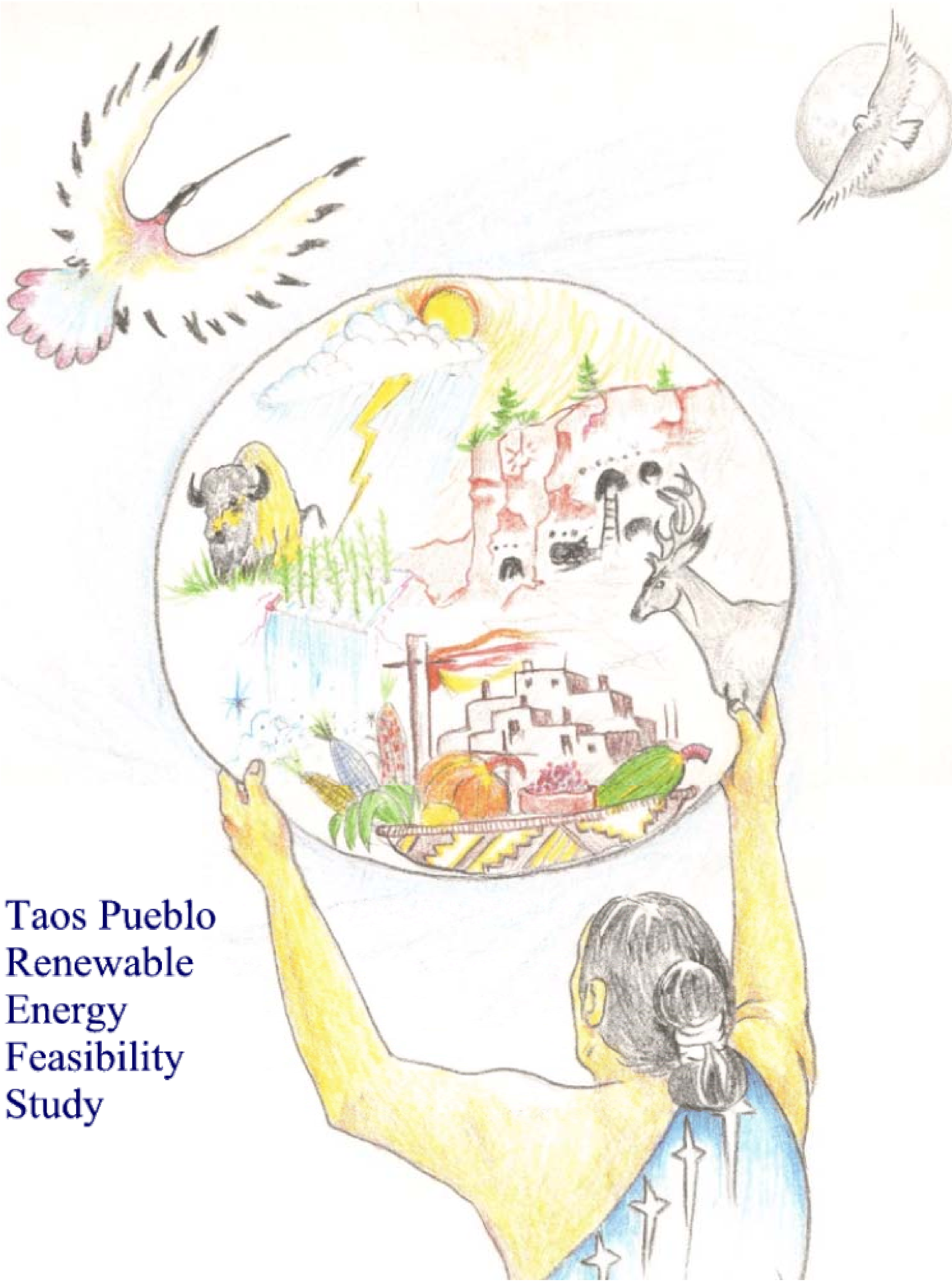

Taos Pueblo Renewable Energy Feasibility Study

"In our Every Deliberation, We Must Consider the Impact of Our Decisions on the next Seven Generations"

From the Great Law of the Iroquois Nation

Drawing on cover by Michael Montoya, Taos Pueblo

Taos Pueblo Renewable Energy Feasibility Study

Taos, New Mexico 2004 – 2006

Final Technical Report

Tribal Energy Program U.S. Department of Energy

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Central Management Systems Taos Pueblo
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Robert Palmer, Financial Director

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I. EXECUTIVE SUMMARY

Taos Pueblo is a federally recognized tribe located in Taos County, New Mexico. Taos Pueblo has a sovereign Tribal Government, consisting of the Tribal Council of Elders, the Office of the Governor and the Office of the WarChief. The Tribal Council is the principal policy and decision-making body. Taos Pueblo Central Management System (CMS) administers a wide range of programs supplying services to tribal members including education, health and social services, judicial services, wilderness management, as well as planning and development offices. The Renewable Energy Feasibility Study was accomplished through the creation of a Renewable Energy program within CMS with office space made available at the Red Willow Training and Education Center. The Red Willow Center is also home of the Summer Sustainability Institute for Taos Pueblo youth. A person with a background in a range of renewable energy technologies was hired to be the director of the Renewable Energy program under the supervision of the CMS Tribal Program Administrator. Taos Pueblo is a traditional community and by integrating the Renewable Energy program within the Central Management System, a fuller sensitivity and responsiveness to cultural, social and natural resource issues was realized.

The scope of the study included all renewable energy resources; biomass, both as electric/heating energy and as transportation fuel, geothermal, hydroelectric, solar and wind. After these renewable resources on lands at Taos Pueblo were quantified, then technologies, loads and power sale potential were studied to determine opportunities where electric energy, heat and transportation fuels could be produced and utilized. These opportunities were then screened by analysis and guidance of what would be culturally acceptable as well as economically viable.

HKM Engineering Inc. of Billings, Wyoming was contracted to complete a preliminary hydroelectric engineering plan based on using irrigation piping as penstocks. A rough draft of a comprehensive business plan was compiled for this hydroelectric plan; research indicated this as the most viable renewable energy project to develop in the near future.

BioEnergy Corporation of Denver, Colorado was contracted, with support from the New Mexico Energy, Minerals, and Natural Resources Department, to complete a preliminary engineering design of a biomass district heating system for a large cluster of tribal office buildings and a health clinic.

Taos Pueblo owns a 11,000 acre tract of land (Tract A) which is open sagebrush traversed by the 115 kV transmission line that supplies all the electric power to Taos and the surrounding communities, including Taos Pueblo. The primary substation for Taos is located immediately adjacent to Tract A. Based on projected commercialization of new solar technologies and projected increases in the cost of electricity, the study revealed there is the potential after 2010 for Taos Pueblo to supply up to 25% of the demand being serviced by the Kit Carson Electric Cooperative. This opportunity represents a long-term strategy for economic development based on renewable energy.

By virtue of the Renewable Energy program being housed at the Red Willow Education and Training Center, a number of renewable energy demonstration projects were implemented in concert with greenhouse construction underway at the Center.

● Subterranean Cooling and Heating System installed in 24'x100' greenhouse

●Photovoltaic array and pump with controller to supply irrigation water

● District heating system based on Garn wood-fired boiler, including radiant heating and fan coil units for 30'x100' greenhouse (funded by New Mexico Clean Energy Grant)

● Biodiesel oilseed crop test plots

These demonstration projects serve several vital purposes by:

1. Determining the feasibility of these technologies and resources in particular applications and confirm viability for use in other locations at the Pueblo.

2. Enabling tribal members to see renewable energy resources being utilized up close and in a familiar context, which not only instills the understanding they work, but also helps overcome negative perceptions about the technologies.

3. Contributing to the successful operation of greenhouses, which are passive solar structures with a critical role to play in revitalizing agriculture.

4. Energizing biomass use thereby supporting thinning of tribal forests, which are threatened by catastrophic wildfires.

Recommendation and Conclusions of the Study:

•A 500+kW hydroelectric turbine can be integrated into the construction of the Indian Ditch pipeline to supply power to critical tribal offices and services as well as export power to Kit Carson Electric Cooperative. This would also operate the two north side municipal wells. This project should receive the highest priority and can funded as part of a Federal water settlement.

•A 15 kW solar installation can supply power to two municipal pumps on the south side that supply water to storage tanks above Taos Pueblo. This will assure a water supply to the community in the event of a sustained failure of the grid. The array could be financed through a low-interest BIA loan to Taos Pueblo Utilities.

•The biomass district heating system at the Red Willow Center should be carefully monitored to determine the usefulness of this approach for other building clusters at the Pueblo.

•Long-term planning of a large solar array in Tract A and a smaller solar array in Tract I (transfer station/old landfill site) using emerging solar technologies should be continued. The Goat Springs Rd./ Health Clinic area is also an excellent site for a solar array that can also be connected to a pump hydro storage facility in the foothills above.

•Taos Pueblo should apply for First Steps grant from the Tribal Energy Program in order to build organizational capacity to carry out the strategic plan developed by the present study. This grant can be coordinated/administered by Taos Pueblo Utilities, which is the best and most appropriate administrative entity to implement or move any energy project planning at Taos Pueblo forward. They are legally able to be an electric utility; the First Steps grant would enable them to expand their operations from just water and sewage, and have the capacity to plan and implement energy projects, the hydroelectric potential in the near term and a 40MW solar array in the long term.

Project Overview

Resources
Baseline assessment of renewable energy resources included biomass, hydro, solar and wind. The results indicated the greatest opportunity lay with biomass, hydro and solar. Cultural issues play a major role in location and utilization of these resources. For instance, mountainous areas near sacred sites, as well as scenic view shed areas ruled out placing anemometers in areas that computer mapping of the area indicated as areas with class 5 and class 6 winds.

Biomass The determination of biomass resources was arrived at through assistance of the GIS files at Taos Pueblo showing vegetation cover and slopes. Offsite studies of fuel loading in forests surrounding Taos Pueblo was data assumed to be representative of forests on tribal lands. The Pueblo has received a Collaborative Forest Restoration Program grant and is currently performing an analysis of thinning needs. This will produce a very accurate quantification of a treatment strategy and resulting biomass material.

Geothermal; Several attempts were made to contract a geologist for a geothermal resource assessment but the contracts did not receive authorization. This may reflect a cultural disposition against using geothermal. However, using research papers available on the Internet and from attendance at Tribal Energy Program conferences, a general overview of ground source heat potential was ascertained.

Hydro; Stream flow data was readily available from four different USGS gages on tribal lands, as well as two additional gages on the Rio Grande. Water flow in irrigation piping and ditches was available from an irrigation rehabilitation plan for Taos Pueblo being designed by HKM Engineering, Billings, Montana.

Solar; Insolation rates for various orientations of arrays were obtained from the National Renewable Energy Laboratory (NREL) database. More site-specific information was obtained from observation of shading due to the direct proximity of mountains and associated cloud cover. Also, passive and active solar technologies are in wide use in Taos valley, which attests to the excellent solar resources here.
Wind; Ten years of wind energy data collected at the Taos Airport was secured from the National Oceanic and Atmospheric Administration. The Taos Airport is immediately adjacent to tribal lands appropriate for wind development; therefore the airport data is applicable.

Energy use
Load analysis was based primarily on existing electric use data tabulated for major tribal offices and operations. The amount of electrical energy needed to supply various clusters or zones of buildings was calculated to better understand how distributed generation could be connected for direct use. Also, locations of planned new construction were taken into consideration in identifying distributed generation sites. Total residential use was estimated based on number of homes with electricity and using a use value somewhat lower than the national average because lifestyles are not energy intensive. Particular attention was given to power requirements for maintaining municipal well pumps for Taos Pueblo Utilities. Also, locations of tribal operations were identified that lacked power but would benefit from power, such as the Buffalo Barn and Tract A.

Natural gas and propane use data was collected for candidate areas of tribal operations for district heating systems. Although most residences have propane primarily for cooking, wood stoves or fireplaces are in practically every home, and this use of biomass was considered an existing practice Transportation fuel use was estimated for tribal operations such as the Roads Department and the WarChief office. Transportation fuel use by individual tribal members was too difficult to ascertain beyond general assumptions about vehicle use.

Technology Analysis

Extensive research was undertaken in regards to biomass, geothermal, hydroelectric, solar and wind technologies that were appropriate to opportunities at Taos Pueblo. For instance, commercial-scale wind turbines did not present an area of interest due to the low average annual wind speeds. Use of dams was not considered due to cultural concerns.

Two major studies were subcontracted. Bioenergy Corporation of Denver, Colorado developed a "Project Plan and Preliminary Engineering Design" for the " Taos Pueblo Biomass District Energy Project". This district plan was for seven buildings including the Taos/Picuris Health Clinic and involved both heat and power and heat only iterations. HKM Engineering of Billings, Montana completed the "Taos Pueblo Hydropower Generation Alternatives" study.

Emerging concentrated solar technologies for electrical generation were of particular interest as the economics of these systems have resulted in 1,000 Megawatt projects being funded in California on the basis of utility power purchase agreements.

Three demonstration projects at the Red Willow Center involved the installation of solar and biomass equipment that presented an excellent opportunity to observe and measure the effectiveness (or lack thereof) of applications of technologies. The benefit of seeing and touching equipment successfully heating buildings cannot be overestimated.

Economic Analysis

The cost of all technologies evaluated above was assessed using life-cycle terms appropriate to those technologies. Biomass boilers have a life of 30 years whereas hydroelectric turbines have a 40 to 50 year life span. Photovoltaics have a yet to be determined life cycle but 30 years is a conservative projection that enables payback to be realized. Wind speeds were too low to be considered adequate for commercial scale turbines.

In depth financial analysis of a hydroelectric project and a solar repowering of municipal wells was completed. Assumptions about the future increase in cost of electricity were keyed to the rate increases occurring locally for the last five years and projections by Kit Carson Electric Cooperative.
Projected increases in cost of propane and natural gas were used to determine viability of biomass projects.

OBJECTIVES

The overarching objective of this study is to inform Taos Pueblo leadership how part or all of energy requirements of tribal members and tribal operations can be met using renewable resources available on site. Energy was considered in the comprehensive sense of electric power and heating, as well as transportation fuels. The study is intended as a strategic plan encompassing opportunities in the present day, in the near future, and long term.

The study also had the objective of determining how use of renewable energy at Taos Pueblo could enable economic development. Demonstration projects implemented in the course of this study were aimed at making commercial
Greenhouses and truck gardening a viable option for tribal members either as individual businesses, or as part of an agricultural cooperative.

This strategic plan is to inform the leadership what options are available for implementation. The study contains in-depth information including preliminary engineering analysis and cost estimates that can be used to develop business plans.

In regards to hydroelectric potential, a completed draft of a business plan is intended to enable leadership to explore funding opportunities for implementation. Taos Pueblo has been negotiating water rights for many years and a settlement, which will include funding, is in process at this time. This settlement is also integrated with an irrigation rehabilitation plan. The hydroelectric business plan was developed as a tool for informing that process. Funds that would be spent on pressure-reduction valves could more productively be spent on turbines that accomplish the same purpose while generating useful energy.

The study also had the objective of showing how sovereignty of energy production could assure security and basic needs being met in the event that there is a sustained failure of the power grid, or that cost of heating fuels have become prohibitively expensive. We are in a period of spiraling energy costs and the highly interconnected power grid can be shut down by a "cascading event" a thousand miles away. The objective therefore was to identify opportunities where water, electricity and motor fuel for critical services could be supplied under any conditions for any length of time.

DESCRIPTION OF ACTIVITIES PERFORMED

I. A. Baseline assessment and B. Technical Assessment C. Load description and economic analysis
Biomass
Geothermal
Hydroelectric
Solar
Wind

II. Cultural and leadership survey

III. Demonstration projects

Note: Baseline resources, technical assessment, load description and economic analysis are aggregated on a renewable resource basis (i.e. solar, wind etc.) as this facilitates communicating integrated development opportunities. It enables tribal leadership to go to any one section such as biomass or hydroelectric and clearly see how resources, location of loads and economics come together.

I. BASELINE RESOURCE, TECHNICAL RESOURCE ASSESSMENT, LOAD DESCRIPTION AND ECONOMIC ANALYSIS

BIOMASS

A. BASELINE RESOURCE

The determination of biomass resources was arrived at through assistance of the GIS files at Taos Pueblo showing vegetation cover and slopes. Offsite studies of fuel loading in forests surrounding Taos Pueblo was data considered to be representative of fuel loading on tribal lands.
The Taos Pueblo forest is comprised of 51,978 acres of timberland and 13,385 acres of woodlands, for a total of 65,856-forested acres under trust. In addition, the Moreno Ranch unit (now called Taos Pueblo Ranch) encompasses 11,760 acres of commercial forest and 3,221 acres of woodlands for a total of 14,891 forested acres. The Pueblo forest is divided up into several different management units. These include Special Management Units, Commercial Forest and the Taos Pueblo Ranch unit. The Special Management Units include a 20,034 acre section referred to as the Rio Pueblo Circle – B that will be managed for Pueblo member's personal use of wood resources. The Commercial Forest unit includes those forested lands west of the Wilderness. These lands will be managed to maintain a pleasing visual appearance. This unit will be managed to achieve optimum wood production for personal and community economic needs. The Moreno Ranch is under purchase contract by Taos Pueblo. The ranch has been used in the past to harvest timber, but most of the timber has been logged, leaving a well-stocked young second growth stand of mixed conifer over most of the forested area.

In conclusion, the Taos Pueblo has approximately 10,000 acres of accessible commercial timberland and about 5,000 acres of accessible commercial woodland. Taos Pueblo received a Collaborative Forest Restoration Program grant in 2005 and is presently assessing treatment strategies. Assuming a conservative yield of 10 wet tons/acre (50% moisture) of small diameter timber, and a sustainable harvesting cycle of treating an acre once every 40 years, then 375 acres treated annually would yield 3,750 wet tons a year. This amount would result in 2,475 air-dry tons (20% moisture). The heating season in Taos extends from October through March or about 180 days, allowing for 14 air-dry tons/day wood consumption or 21 "as is" tons/day on a sustainable basis. This amount is separate from what is available for residential consumption, and would therefore be available for supplying larger scale biomass heaters connected to district heating systems, commercial greenhouses, and large buildings.

Offsite resources include the Carson National Forest and area sawmills. Carson N. F. is planning to treat over 100,000 acres in the next ten years generating about 30,000 oven dry tons per year in wood waste. Presently, large amounts of thinning wastes are burned on site for disposal. Taos Pueblo is surrounded by the Carson National Forest in a 75 mile radius; therefore the hauling distances are practical for supplying projects at the Pueblo without prohibitive transportation costs. A sawmill located just two miles from Taos Pueblo generates about 4 tons of wood wastes a day which are available at a nominal cost.

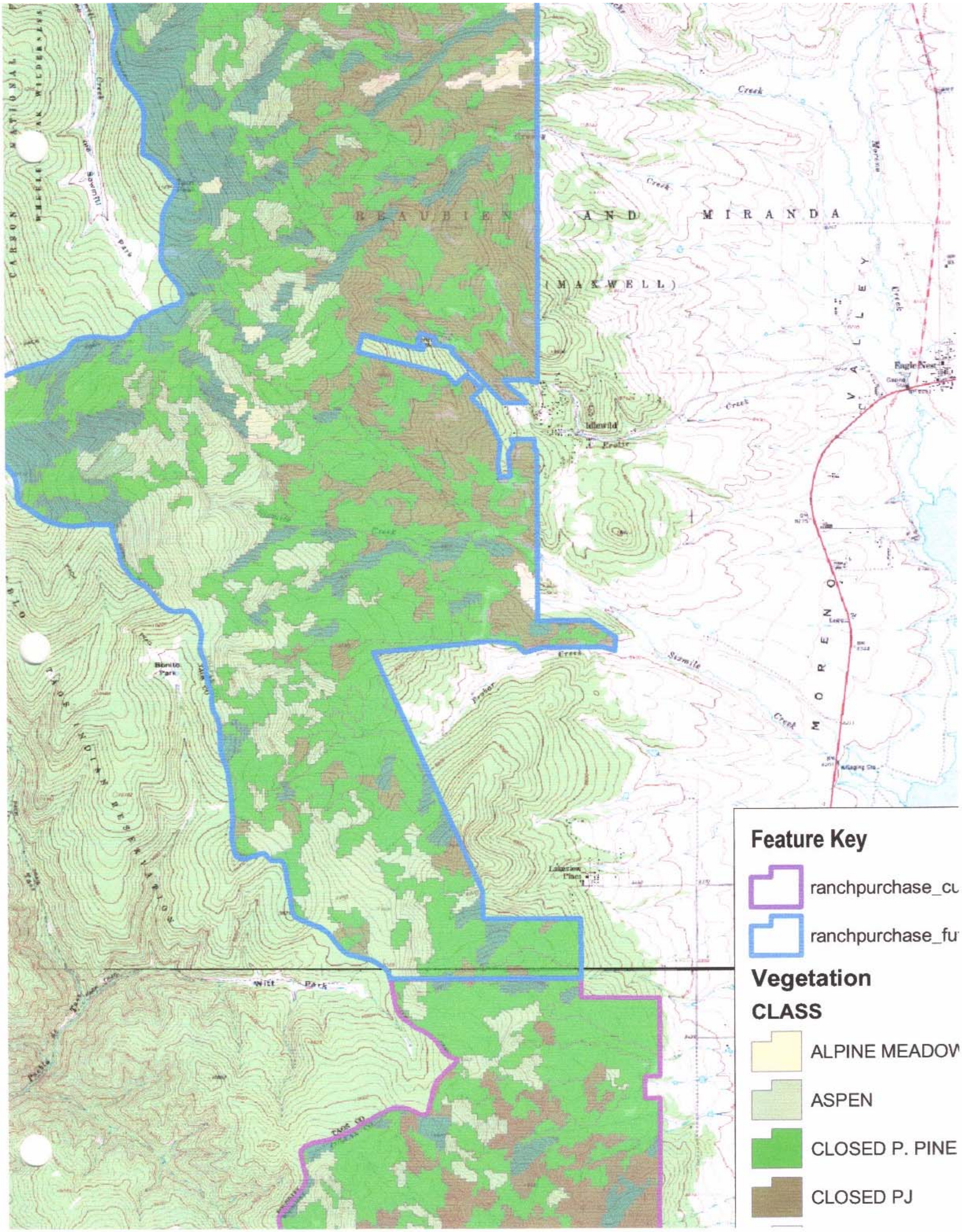
A study by New Mexico State University on biomass resources in the Angel Fire area and surrounding region, which is near the Taos Pueblo Ranch, showed 234,000 bone dry tons per year available.
(La Jicarita News, April 2000)

The commercial timberlands of Taos Pueblo are characterized below:

Taos Pueblo Ranch Vegetation Cover

For current ranch purchase (south of Witt Park) **approx 4815.43 acres:**
Pinon-Juni = 686.74
Ponderosa = 2519.78
Aspen = 1173.77
M. Conifer = 419.49
*remaining nonwooded rip = 15.67

For future ranch purchase (north of Witt Park**) approx 10616.58 acres:**
Pinon-Juni = 2528.9
Ponderosa = 4305.53
Aspen = 1682.25
M. Conifer = 1677.46
*remaining nonwooded rip (7.62) grass/shrub (220.35) alpine meadow (112.18), wet meadow (82.28)


Feature Key
ranchpurchase_cu
ranchpurchase_fu
Vegetation
CLASS
ALPINE MEADOW
ASPEN
CLOSED P. PINE
CLOSED PJ
BEAUBIEN AND MIRANDA
(MAXWELL)
MORENO VALLEY
Eagle Nest
Idlewild
Bonito Park
Witt Park
Creek
Sixmile Creek
CARSON NATIONAL

OTHER BIOMASS FUELS

In 2004 three test plots of sunflowers, mustard and canola were planted at the Red Willow Center to determine the feasibility of cultivating these crops for biodiesel production. The plants thrived to varying degrees based on watering regime, indicating that even with a minimum of irrigation these crops grow well here at Taos Pueblo. Due to a late planting date, and a severe early frost, seed yields were not determined. In 2006, another test plot of canola and mustard was planted and survived an early frost that killed off corn and squash, exhibiting a hardiness that makes these crops adaptable to the short growing season here at Taos Pueblo. The land available for these crops on a larger scale is difficult to determine. Assuming that 640 acres were put in cultivation, and based on a yield of about 50 gallons/per acre, then about 32,000 gallons of biodiesel could be produced from the oilseed harvested. Canola oilseed produces a biodiesel with superior cold-flow properties, a valuable quality given the cold winters here. Sunflowers rotate well with wheat crops.

Test crop of mustard seed at Red Willow Center Sept. 2004

Algae is a biomass crop that can be utilized for extraction of lipid oils for biodiesel production, or either fermented or gasified into ethanol fuel. Taos Pueblo has the resources of land, water, ample solar and sewage to cultivate algae. An acre of land utilizing high-efficiency bioreactors can produce enough algae derived oil to make over 15,000 gallons of biodiesel a year. The development of an on-site sewage treatment plant at Taos Pueblo could be used to grow algae while recovering an additional 40 acre feet of water per year.

Rabbitbrush (chamisa) is an arid climate plant that possesses a high-energy content due to the presence of rubber compounds. McLaughlin and Hoffman (1982) suggest that var. *bigelouii* can produce 12.5 barrels/ha of biocrude at a cost of $50.00 per barrel.
Chamisa has been identified as one of the more promising arid land species for the production of biocrude (a hydrocarbon-like chemical fraction of plants which can be upgraded to liquid fuels and chemical feedstocks) or the plant can be gasified to produce synthesis gas. Finding the cyclohexane extract to be 15.1%, the ethanol extract 20.8%, McLaughlin and Hoffmann (1982) calculated 13.2 kBTU/lb in the extractables, a biomass yield of 4.5 MT/ha (2 U.S. tons/acre) or 12.5 bbls, at a per barrel cost of $50.00 or $13.10/million BTU. According to the Dept. of Agriculture Rocky Mountain Research Station, rubber rabbitbrush has a deep root system and can establish rapidly, even on severe sites. It has been successfully cultivated since 1886 and and can reclaim areas like mine sites and roadsides. Very importantly, there is equipment and a technique for harvesting the chamisa. A use level of 50% can be maintained over long periods of time without affecting the size of crown. Assuming a use rate of 50%, this would yield one ton per acre per year. For purposes of gasification, the market for gasification biomass is typically $25. to $30./ton. therefore this would be the gross earnings per acre per year.

Taos Pueblo has 10,000 acres of arid sagebrush country in Tract A that could be cleared and some portion could be planted with rabbitbrush, as well as grasses for grazing livestock such as buffalo. Based on 10% of the area or 1,000 acres, and 12.5 barrels of biocrude per hectare converting to 5 barrels per acre, would total 5,000 barrels of biocrude per harvesting cycle. The initial clearing of the sagebrush on the entire 10,000 acre Tract A, based on 5 tons/acre yield, would produce 50,000 tons of biomass. A 10 year plan for transforming Tract A into energy crops and livestock grazing would entail 1,000 acres a year of clearing sagebrush, yielding 5,000 tons of sagebrush biomass a year.
Assuming 5,000 acres of Tract A (half of the area) were to be transformed into a chamisa plantation, then in addition to the 5,000 tons of sagebrush, the area would produce 5,000 tons a year of high energy biomass. (approximately 8,000 btu/lb./ bone dry) on a sustainable basis. This volume could supply 30 tons a day on an annual basis to a gasification system with 90% availability. This resource, combined with the 20 tons of wood a day referenced above from Taos Pueblo commercial woodlands would be adequate to supply a 50 ton/day gasifier.

A landowner adjacent to Tract A has successfully cleared sagebrush from over a section of land and converted it to grazing grasses. The U.S. Natural Resource Conservation Service has funding available to pay up to 50% of the cost of this land practice.

B. TECHNICAL RESOURCES

WOOD-FIRED BOILERS, DISTRICT HEATING

Wood is traditionally used in woodstoves for residential use and this heating source is in wide use. The use of wood for centralized heating for larger buildings or for use in district heating systems is commercially available and in wide use in the Midwest, New England and Europe. The Ouje-Bougoumou First Nation in Quebec is an entire Native-American community heated by a wood-fired district heating system.
The most proven technologies can be divided into fully-automated combustion biomass boilers or manually operated combustion systems. The former systems are larger and can be integrated with electrical generation as well. A grant from the State of New Mexico was utilized to develop a preliminary engineering design for a district heating system in the Indian Health Service Clinic area. A district heating system is where a single boiler supplies heat to a complex of neighboring buildings by means of hot water delivered through

underground insulated piping. An example of an entire tribal community heated by a district system is shown below. A district heating pre-engineering study contracted as part of this feasibility study featured a fully-automated system with supply lines servicing the Health Clinic, Taos Pueblo Utilities, Roads and Realty, Forestry, and Housing. Due to the small heating loads at most buildings coupled with the high cost of buried insulated water lines, the economics of this system were not promising. However, supplying the Health Clinic and a cluster of commercial greenhouses immediately adjacent to the Clinic did merit further consideration. See reproduction of study below.

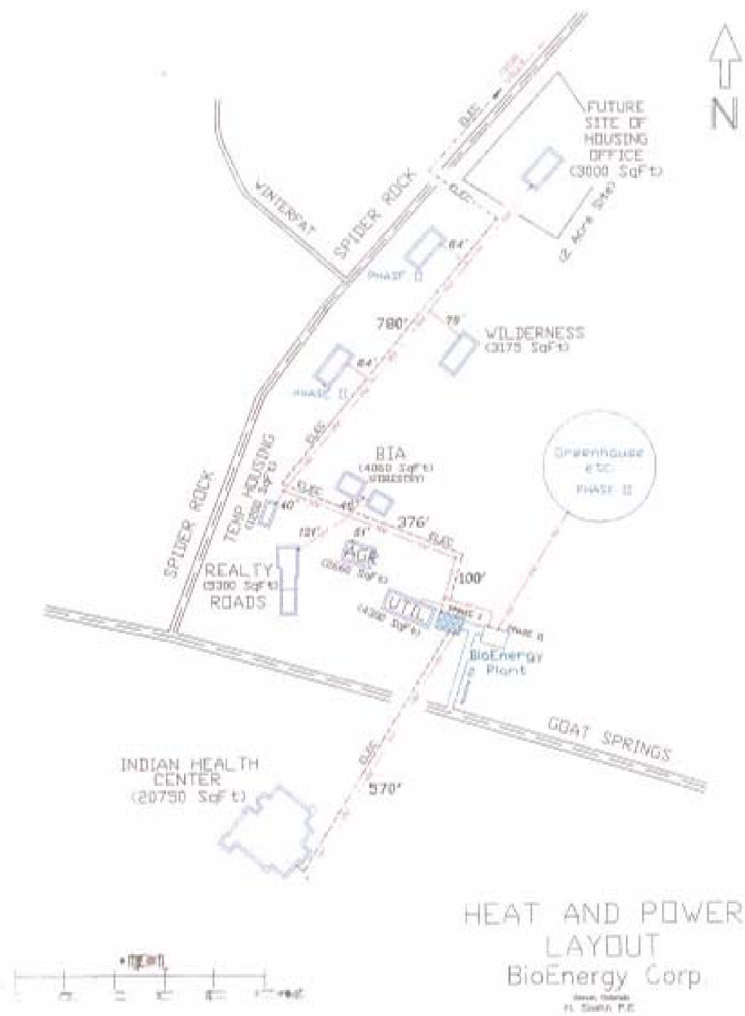
The manually-operated systems are much lower in cost and less prone to mechanical break-downs. The Garn wood boiler with thermal storage capacity is used in over twenty public schools in Minnesota and has a very high efficiency due to an afterburner those combusts gasses that would otherwise go up the smokestack. The Garn in fact does not even require a vertical smokestack. A large water tank surrounding the combustion chamber can store up to 2,135,000 Btus of heat which can be charged from a 2 hour long fire burn. A single one-hour fire can heat a 5,000 sq. ft. building for 24 hours with a thermostat controlling delivery of hot water from the storage tank.

C. ENERGY LOADS AND POTENTIAL PROJECTS

A preliminary engineering study contracted through a Forest Health Collaborative grant from the New Mexico Energy, Minerals, and Natural Resources explored a district heating system concept developed by this feasibility study. Key parts of the study are reproduced below. The study was completed by BioEnergy Corporation of Denver. It should be noted that the cost per foot for trenching used by BioEnergy was $120./ft. This is a cost perhaps applicable to Denver or mountainous terrain. Local contractors have quoted this researcher that the trenching cost is more on the order of $4/ft. to $5/ft. This cost change has been noted in pencil on page 29 below.

On the other hand, the study uses cost for wood at $15/ton which is optimistically low. The cost is more in the range of $30/ton to $40./ton. This is offset by the fact that the price of natural gas has risen higher than indicated in this report.

Figure 2. Heating Design



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Goat Springs Rd./ Spider Rock Rd. Area District Heating System Design

5.0 TAOS HEATING & POWER REQUIREMENTS

A detailed study was performed on the heat and power load that all of the Community buildings require, based on heat and electric bills, over the last year (2003-2004). Option A (heat only) will supply all of the heating requirements to all Community buildings using a hot water main line and branch lines that supply individual buildings via hydronic units located in each. Option B calls for the complete heating requirements for all Community buildings plus the production of 10kW steady power production for use by the IHC. In the event of grid power failure, the power would be switched to the Community water well pumps to assure their steady operation for however long a power the outage lasts. The IHC has an adequate backup generator to satisfy power demand in the case of such a power outage.

5.1 Heating Demand

The following chart shows heat usage in therms for each month and by each building. Where a bill or record for several months does not exist, an estimate was made by the ratio of building square footage to some other building's known heating load, where that building has a similar use, or if the record is missing for only a month, a simple average was used. All estimates are shown in italics. All of the heating loads were within DOE national averages, as expected on an hourly or on a square footage basis for the Taos climate.

Energy summary of all buildings: heat

Building	Month–	1	2	3	4	5	6	7	8	9	10	11	12	
Utilities	therms	334	369	255	139	63	12	6	6	6	40	222	317	1768
	bill	239.10	279.03	205.49	122.01	60.92	23.84	19.13	19.10	16.88	38.04	147.15	201.82	1373
area, ft2	Btu/ft2		8578											0.7761
4300	Btu/ft2/hr		12.8											cost/th
	Btu/hr		54889											
Ro/Re	therms	524	577	375	303	151	45	26	19	64	182	316	542	
	bill													
area, ft2	Btu/ft2		10895	375	303	151	45	26	19	64	182	316	542	
5300	Btu/ft2/hr		16											
	Btu/hr		85927											
Agr	therms	274	416	188	164	76	15	13	10	32	91	159	272	
	bill	199.27	312.44		144.72		25.88							
area, ft2	Btu/ft2		15622											
2660	Btu/ft2/hr		23.2											
	Btu/hr		61836											
Wilderness	therms	314	346	225	182	91	27	16	11	38	109	189	325	1872
	bill	238.14	262.61	183.07	154.59	80.79	34.5	26.38	23.33	36.07	80.04	127.7	206.59	1454
area, ft2	Btu/ft2		10895											0.7766
3175	Btu/ft2/hr		16.2											cost/th
	Btu/hr		51475											
BIA	therms	772	715	547	244	136	12	4	4	6	151	299	534	3424
	bill	532.29	526.49	432.45	202.36	113.67	23.87	18	17.97	16.95	106.2	193.83	331.24	2515
area, ft2	Btu/ft2		17611											0.7346
4060	Btu/ft2/hr		26.2											cost/th
	Btu/hr		106399											
IHC	therms	2266	2326	1623	1536	1229	1164	1081	1116	1128	1520	1439	2171	18599
	bill	1532.4	1668.9	1219.9	1180.9	898.61	856.4	807.01	826.1	815.19	957.9	895.96	1312	12971
area, ft2	Btu/ft2		11210											0.6974
20750	Btu/ft2/hr		16.7											cost/th
	Btu/hr		346131											
housing	therms	93	103	71	39	18	3	2	2	2	11	62	88	
trailer	bill													
area, ft2	Btu/ft2	7779	8578	5921	3241	1473	283	131	131	134	935	5156	7365	
1200	Btu/ft2/hr		12.8											
	Btu/hr		15318											
New Hous.	therms	233	257	178	97	44	8	4	4	4	28	155	221	
Office	bill													
area, ft2	Btu/ft2	7779	8578	5921	3241	1473	283	131	131	134	935	5156	7365	
3000	Btu/ft2/hr		12.8											
	Btu/hr		38294											
total	therms	4717	5109	3390	2666	1791	1283	1149	1170	1278	2121	2779	4381	
			760269											
Feb hrs=			Btu/hr											
28*24=			peak											
672														
tot therms	31836													

assumptions and notes

1. numbers in italics are estimates based on square footage and known heating

2. all data reflects 2003-2004 time frame

During the month of February the Community buildings have the greatest heat demand. For that reason specific heating parameters are noted. The following is a brief summary of the heating demand for several Community buildings compared with several national building data parameters for natural gas from the Energy Information Agency, Office of Energy Marketing.

Energy Intensity thousands btu/ft2) based on annual consumption

1	EIA: data	category:	all buildings	1k-5k ft2	office	Rocky Mountain	>7000HDD	40-48 hrs weekly
			28.6	56.9	24.5	35.4	51.4	34.6

2	building data	therms	floor area	thousands Btu/ft2
	Utility Bldg	1768	4300	41.1
	Wilderness	1872	3175	59.0
	BIA	3424	4060	84.3
	IHC	18599	20750	89.6

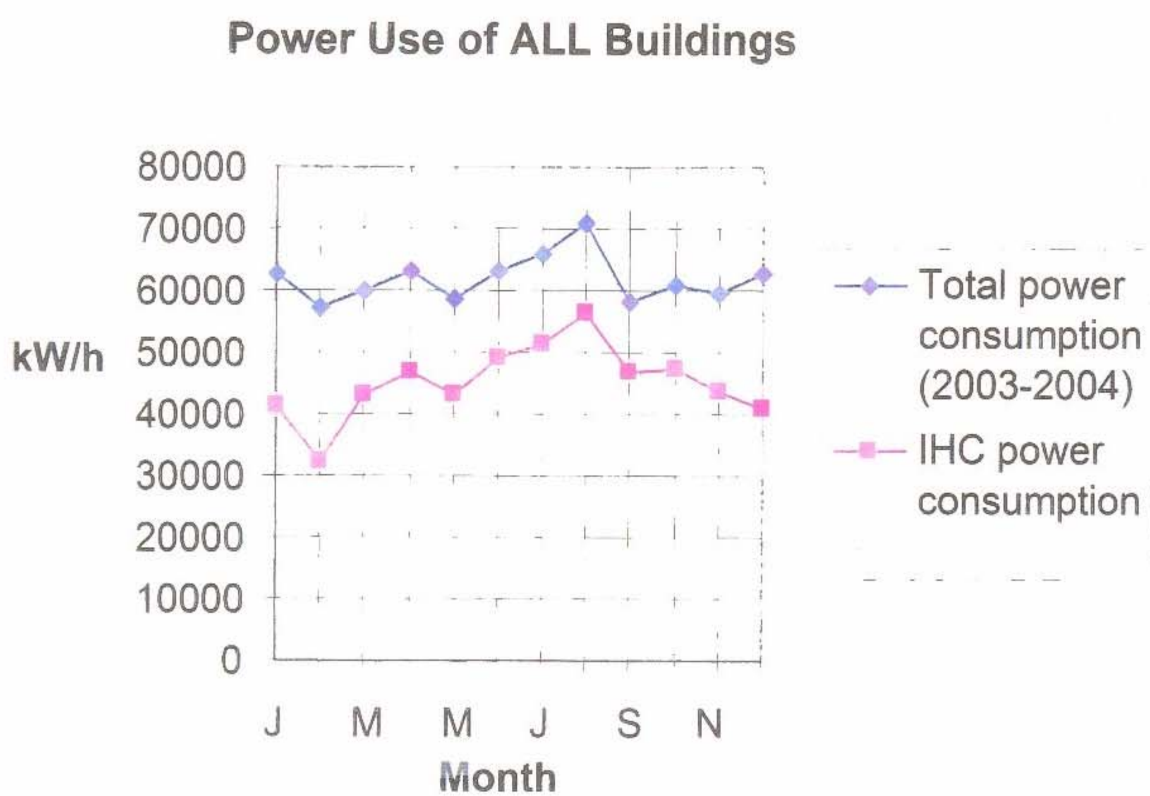
The Utility and Wilderness buildings are within the norm of areas, such as Taos that have more than 7000 Heating Degree Days (HDD). The BIA building appears high and the Indian Health Center, because of its 24/7 function as a health facility is lower than the national average of 147 (not shown), which includes all heating needs (hot water, cooking, sterilization, etc).

In summary, the following chart illustrates the heat consumption for all Community buildings compared to the IHC.

5.2 Power Demand

The same procedure was employed to analyze the power demand for the Community.

The following graph shows the data in summary form for all buildings and separately for the IHC. The IHC accounts for approximately 73% of total Community power consumption.



6.0 SUBSYSTEM FUNCTIONAL DESCRIPTION, DESIGN CRITEREA AND ENGINEERING ANYLASIS

This section discusses in detail the various components that makeup a biomass-fueled heating or biomass-fueled combined heat and power system. The subsections follow the wood fuel's course from the time of delivery to combustion in the boiler system. From there the subsections follow the steam or hot water through the entire heat and power loops and the return of the hot water to the plant.

6.1 Fuel Storage

Once the fuel resource has been identified and the biomass wood is processed and transported to the plant facility, the fuel should be delivered to covered storage area. For Option A (heating only) "storage" refers to approximately 5 days worth of wood calculated to provide fuel for continuous peak heating requirements in February, the coldest month. So in February, if conditions are severe enough, delivery of wood will occur once every 5 days. The rest of the heating season will not see such a demand so the designed storage volume will last considerably longer than 5 days. For Option B (combined heat and power) the plan is to run the system at near peak continuously in order to produce 10kW power. Under this scenario, a regular schedule of weekly delivery (year in and year out) will require 7 day storage volume.

The following table reviews estimated building and storage requirement for Options A and B.

Bio-Energy plant fuel storage capacity Option A – heat only; Option B – heat and power			Option A	Option B
a. building on concrete slab			40x25x20ft	50x25x20
	boiler room section		25x25ft	25x25
	fuel storage section		15x13	25x25
	total footprint		1000ft2	1250ft2
b. storage volume			1950ft3	6250ft2
	wood aggregate density	500lb/yd3		
	peak system design usage		2.9 tons/day	7.6 tons/day
	storage capacity		6+ days	7.5+ days

6.2 Fuel Handling, Combustion and Boiler System

This section describes the integrated fuel feed, combustion, and handling system. The system components are not necessarily the final choices but do represent very typical elements for 30-60 boiler horsepower sized units.

6.2.1 Option A

Based on the peak heat-only requirements calculated for the coldest month of February of 800,300 Btu/h and allowing for some excess capacity so that 2-3 buildings the size of the Utility buildings and its requirements could be added in a Phase II program at some future date, a 30 bhp hot water boiler (approximately 1 million Btu/h capacity) will be adequate.

Figure 3 (page 11) shows both Option A system in schematic form.

The path of the heating is as follows:
The 30 bhp hot water boiler produces 15 psig 195+ F hot water which directly supplies two main 4" ID loops – one to the IHC and the other to the Community buildings. The hot water heat (flow rate is estimated to be approximately 38 gpm) is transferred to the IHC system with a heat exchanger so that no part of the existing internal hot water heat supply is altered. Valving and electronic controls will regulate and adjust the incoming hot water system to the heat exchanger. In the event of biomass plant down time, the valving and switch gear will permit the IHC's existing gas-fired hot water system to pick up the heating load. The other loop – to the Community buildings – will operate in much the same manner. Hot water (flow rate is estimated to be 50 – 60 gpm) through the main line will be available to branch building lines that connect inside the building to a heat exchanger that then supplies the two internal hydronic pumps with each building's own hot supply that then gets routed to either a hydronic heater for forced-air office heating or to a stand-alone ceiling mounted hydronic heater for garage heating.

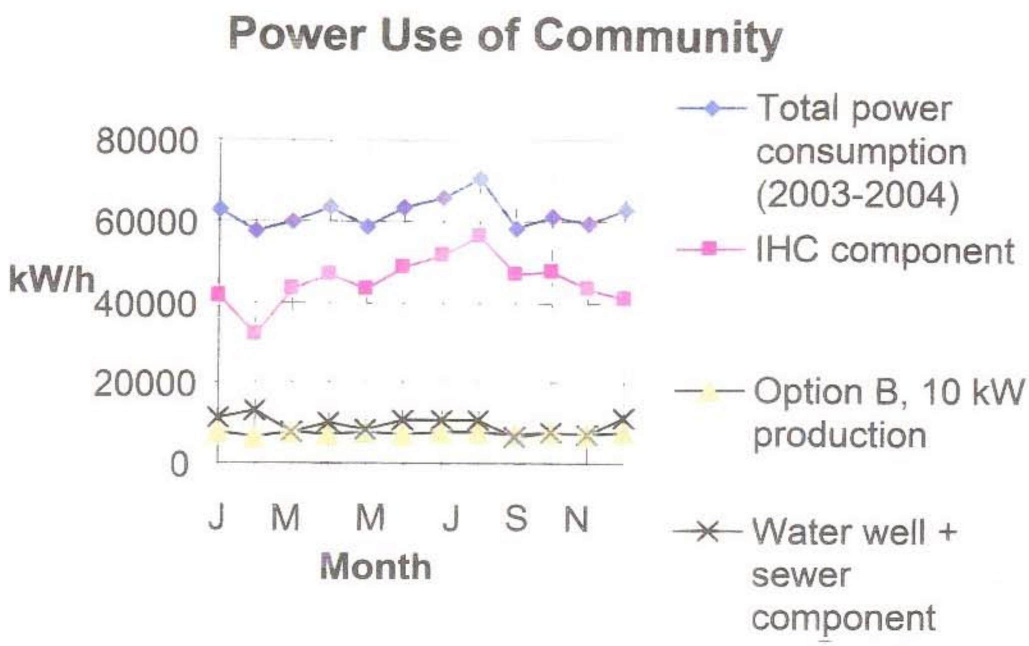
6.2.2 Option B

To produce electric power, 150 psig steam from the boiler enters a single stage turbine that drives a 3 phase 480 volt synchronous electric generator Based on these requirements, a 60 bhp 150 psig steam boiler was selected and will produce 2 million Btu/h. The fuel feed, combustion, and boiler system components are conceptually the same for the Option B plant as described for Option A.

The path of the heat flow for Option B is very similar to the one described above for Option A. For Option B, heat is carried out of the 60 bhp boiler as 150 psig steam. The steam goes directly through a drip leg or pot/baffle that removes any water moisture from the steam. The dried steam is then piped directly into the turbine which connects to the synchronous generator to make electricity. Steam exits the turbine a pressure a few psi above atmospheric and then is run through the main heat exchanger. The steam loses its heat and exits (mostly) as hot water. This return water is treated and added to from the water make-up system and is then sent through the deaerater, which takes out any air in the supply. The pump then returns the water to the boiler where the heat generation loop begins again.

6.3 Electric Power Generation System

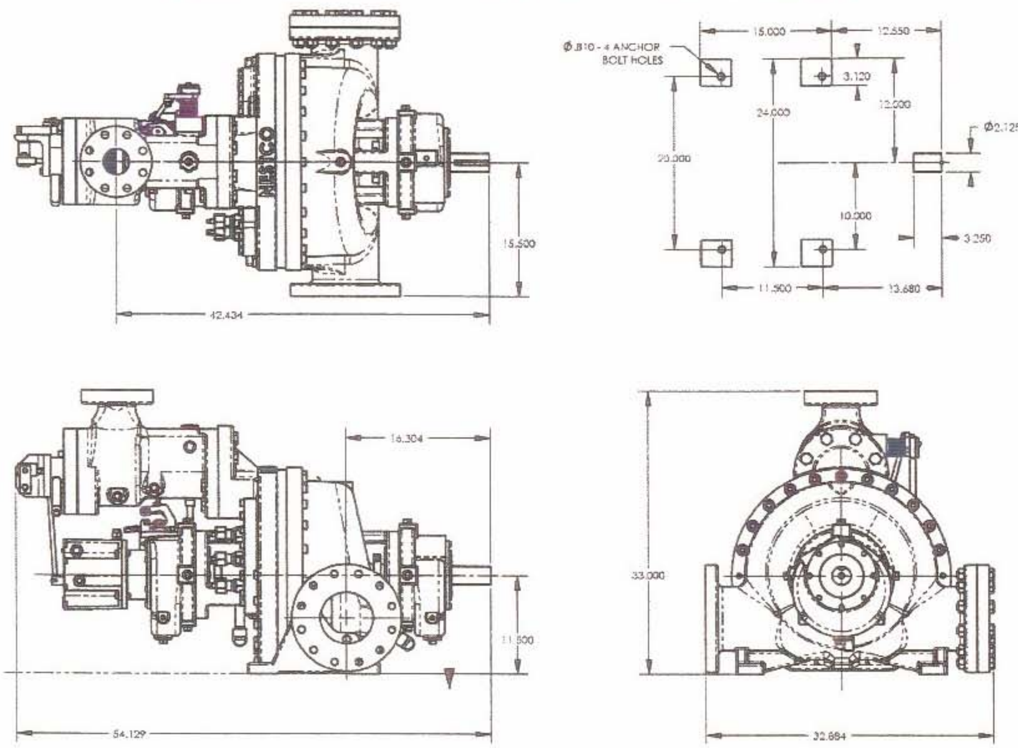
Option B calls for the steady production of 10kW of power that will supply part of the IHC's daily power requirements and will be switched to supply the power for the water well pumps in case of emergency, when a power outage is experienced from the grid. The IHC's average monthly usage is 45200 kWh and 10 kW power on an average monthly basis is 7300 kWh – so the wood-fueled electric production will supply approximately 16% of the IHC's needs. Shown below is a graph of how 10 kW continuous power on a monthly basis compares with IHC consumption. Equally, the 4 water well pumps and sewer vault's power demand is shown on the graph – where the average power use is 13 kW, 30% above the 10 kW power production. Since emergency power for the wells and sewer with power would be switched over only upon grid failure, Option 2 power would be adequate for emergencies.



Initially, both induction and synchronous units were investigated. Turbine-induction generator units are cheaper than turbine-synchronous units by 30-40%. However, an induction generator takes its excitation from the utility grid and has no ability to produce voltage until it is connected to the utility. In the event of a power outage, no electricity can be generated. Since having stand-alone power is deemed essential in order to supply power to the Community water well pumps in case of power outage, a synchronous unit must be employed. A synchronous generator has an exciter that enables the generator to produce its own reactive power and regulate its voltage and so can run independently of any other power source. Synchronous generators require a speed reduction gear and more complex electronics.

The single stage steam turbine that best suits the operational requirements is NESTCO 17, also designated as the Dresser-Rand Model 401RT model. Associated with the turbine is a speed reduction gearbox with integral lubrication system, high/low flexible couplings, all mounted on a structural steel baseplate. All of this connects to the synchronous 480 volt, 3 phase, 60 Hertz generator. A turbine/generator control panel operates the basic control/protection functions.

NESTCO-17 BASIC LAYOUT



NESTCO-17 Design Specifications

Maximum Inlet Pressure: 700psig
Maximum Inlet Temperature: 825F (440C)
Maximum Exhaust Pressure: 175psig (1)

Maximum Speed: 6300 rpm
Output: up to 1200 hp (1200hp @ 6000rpm, 852kW)

Inlet Size: 3" Cl 250 FF/600 RF (76mm)
Exhaust Size: Dual 6" Cl 250 FF/300 FF (152mm)
Shaft Extension: 2.125" (54mm)
Nozzles: 10 max

Unit Weight (approx.) type 1 / 2: 1525 / 1700 lbs

NESTCO-17 Material Specifications

Nozzle Block: 11-13 Cr Stainless Steel

Steam Glands: 300 series Stainless Steel

Throttle Valve Plug: Hardened 17-4 PH SS

Throttle Valve Cage: Hardened 11-13 Cr SS

Blades: Hardened 11-13 Cr SS

Rotor DISC: Heat Treated 4140 Alloy Steel

Rotor Shaft: Heat Treated C1144 Steel

Iron Valve Body and Casings: ASTM A 248 Cl 40

Steel Valve Body and Casings: ASTM A 216 Gr WCB

6.4 Heat Supply Piping and Hydronic Heating Systems

This section describes all of the piping and heat exchange components external to the plant building. Heat is delivered to the individual Community buildings via a main hot water pipe carrying hot water at approximately 190F. Two 4" main lines leave the plant building: one goes south to the IHC and the other extends west and then north to supply heat to all of the other Community buildings. Routing to the IHC is very straight forward in that it is a 570ft straight line crossing under Goat Springs Road and proceeding to the lower corner of the IHC where the emergency diesel generator set is fenced in and also where the double doors opening into the boiler room are located.

The cost of digging pipe ditch is never cheap, so pipeline routing must be considered very carefully. To that end, the route to the Community buildings was walked, photographed and discussed with Richard Mason, the Taos Pueblo's Renewable Energy Coordinator.

The following **Figure 7** illustrates a typical building heating schematic. Both existing natural gas and hydronic heating systems are shown.

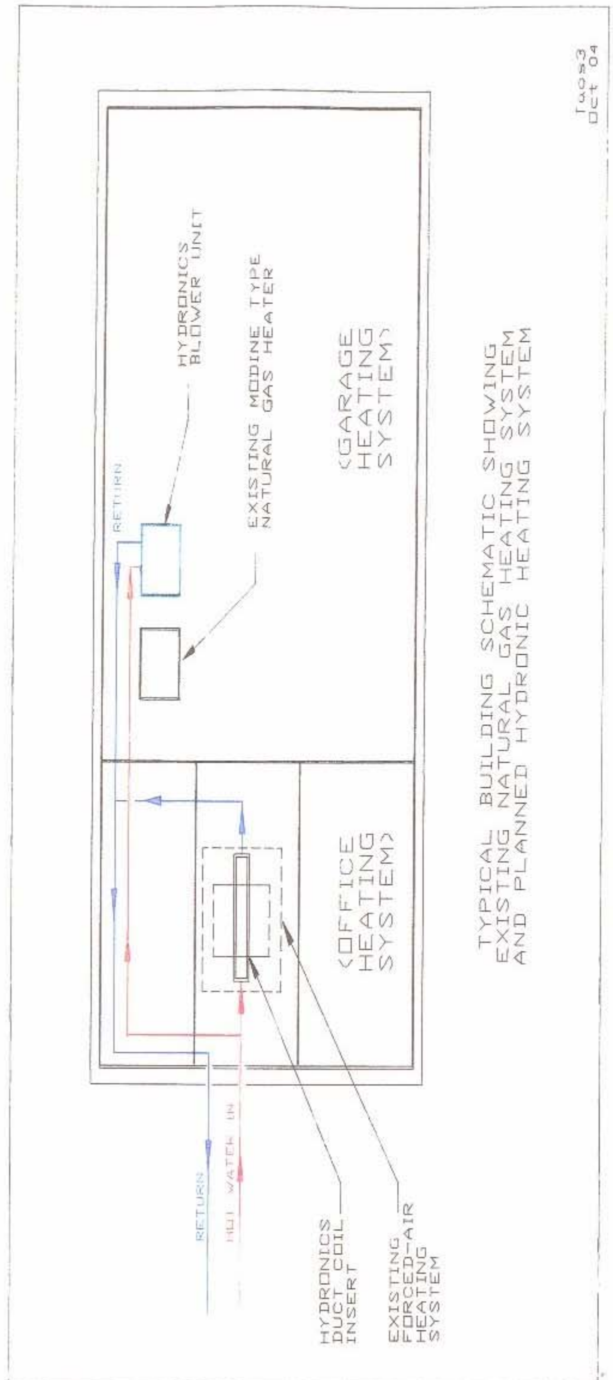


Figure 7. Typical Hydronic Heating Schematic

7. FUEL THROUGHPUT

Fuel consumption and resultant emissions and organic waste in the form of fly ash, are difficult to measure with any certainty at this preliminary design stage. Option A is expected to consume a relatively small amount of fuel and the resulting air quality impacts are anticipated to be minimal. Option B will consume more fuel and therefore produce more emissions, however optimized combustion can reduce emissions factors to very acceptable levels. Fly ash is expected to be approximately 2% of total fuel input and can easily be recycled in a number of useful ways. A more detailed air quality impact report will be possible after the specific equipment is selected for the combustion process.

7.1 Option A Fuel Consumption

Under this hot water heat option, the maximum full capacity output requires a peak wood consumption of 2.9 tons of wood per day, where each ton of wood makes available 10 million Btu (approximately 5000 Btu per lb). This peak production varies considerably through the heating season at Taos so an annual wood requirement is calculated to be approximately 500 tons, based on the heat demand of the IHC and all other Community buildings throughout the year.

7.2 Option B Fuel Consumption

Under this heat and power production option, the maximum full capacity output requires wood consumption of 7.6 tons of wood per day. The wood consumption in this scenario is fairly constant since 10 kW power production is a stated goal so the annual wood consumption becomes approximately 2769 tons.

8.0 COSTS & SAVINGS

This section puts in summary form the capital costs of plant equipment and the monthly and annual savings associated with Option A and Option B when wood fuel is substituted for natural gas and when (in the case of Option B) 10 kW of electric power is produced and substituted for equivalent grid power.

8.1 Capital Costs - Option A

The following is an estimate of all major component costs for Option A, which requires replacement of heat produced by natural gas with wood for all Community buildings including the IHC. Refer to the end of this section for additional breakdown of subsystems represented in this summary.

Option A System Capital Cost Estimate

Bio-Energy system components:		cost	cost fraction
a) site preparation, concrete foundation/floor, standard steel building (40x25)(includes fuel storage), landscaping		$50,000	0.085
b) fuel handling, combustion, boiler equipment	100500		
mechanical installation	12500	113,000	0.193
c) building/plant internal finish, piping, controls		15,000	0.026
d) heat exchanger - IHC		1,500	0.003
e) hot water piping system costs	-$250,000. reduction	387,000	0.660
f) hydronic equipment with installation		19600	0.033
			0.000
			0.000
Total		**$586,100**	**1.000**
	Revised	336,000	

assumptions and notes:

1. all analysis is based on an assessment level engineering estimate; further refinements will be made in the actual engineering design work that will include engineering, procurement and installation costs
2. bioplant internal finish includes sprinkler system
3. fuel handling, combustion, boiler system includes exhaust stack
4. see separate sheets, where appropriate, for costs on specific items

8.2 Monthly & Annual Savings - Option A

In this section, the cost savings on a typical monthly and annual basis are presented. Natural gas prices are assumed to increase by about 15% each year above the first year of operation, where the price is the current average paid by the Community buildings. Wood prices are held at a constant $15/ton. This reflects the Taos area absence of a competitive market for wood fuel and the very large availability of wood on Pueblo, BLM, and National Forest lands. The price also reflects the transportation, chipping/grinding, and handling of the fuel so that it has the appropriate size and quality for the plant operation (typical 2" chips clean of pebbles, rocks, and other debris).

The following chart shows in summary the first year's savings associated with Option A heating of all Community buildings with wood instead of natural gas.

Option A - heat only, monthly savings and costs

Month	therms	cost nat gas	wood use tons	wood cost $15/ton	savings at $15/ton
1	4717	$3,366	74.7	$1,120	$2,246
2	5109	$3,646	80.9	1213	2,433
3	3390	$2,419	53.7	805	1,614
4	2666	$1,902	42.2	633	1,269
5	1791	$1,278	28.3	425	853

6	1283	$916	20.3	305	611
7	1149	$820	18.2	273	547
8	1170	$835	18.5	278	557
9	1278	$912	20.2	303	609
10	2121	$1,514	33.6	504	1,010
11	2779	$1,983	44.0	660	1,323
12	4381	$3,126	69.3	1040	2,086
	31834	$22,717	503.9	$7,559	$15,158
		$0.7136		15	

assumptions and notes:
1. natural gas price of $.7136/th is a blended average of IHC, BIA, Wilderness, and Utilities buildings with the most complete 12 month records
2 natural gas usage is based on existing bills stated consumption
3. wood consumption is based on .7, .95, .95 combustion, plant system, and pipe system efficiencies and wood heat content of 5000 Btu/lb = 10 million Btu/ton
4. wood cost @ $15/ton is representative of an excellent rate for community slash pile use and for cost of Taos Pueblo forest thinning operations through the joint BLM-Pueblos Joint Assistance Agreements; see separate spreadsheet for wood cost breakdown

The following shows the savings associated with Option A over a twelve year period, in which the price of natural gas is assumed to increase by a simple 15% per year above the current average cost of natural gas per therm. Approximately 69% of the capital costs under this scenario have been recovered at the end of twelve years (406,794/586,100 = .69)

Option A Annual Savings and Costs

year	therms	cost nat gas	wood cost $15/ton	savings at $15/ton	cumulative savings at $15/ton
1	31834	22717	7559	15158	15158
2	31834	26124	7559	18566	33724
3	31834	29532	7559	21973	55697
4	31834	32939	7559	25381	81078
5	31834	36347	7559	28788	109866
6	31834	39754	7559	32196	142062
7	31834	43162	7559	35603	177665
8	31834	46569	7559	39011	216676
9	31834	49977	7559	42418	259094
10	31834	53384	7559	45826	304920
11	31834	56792	7559	49233	354153
12	31834	60199	7559	52641	406794

0.7136

Assumptions and notes:
1 annual heating requirements are based on best available information on past usage for all buildings.

2 natural gas current price $.7136/th is blended average on buildings with most complete records;
cost increases are based on industry estimates of 15% annual increase from year one cost
3. wood price defined to be constant $15 - insufficient data on market forces for wood in the Taos area that could affect price in foreseeable future

8.3 Operation &Maintenance – Option A

The following is a brief estimate of typical operations and maintenance (O&M) costs associated with a typical biomass facility of this size. Labor costs are believed to be appropriate for the Taos area.

O&M annual costs Option A

	labor rate $/hr	hrs/yr	annual cost
Option A			
plant	25	364	$9,100
material			1200
total			$10,300

Assumptions and notes
1. plant maintenance assumes approx. 7hrs/week duty
2, materiel costs typically are $100 per month

8.4 Capital Costs - Option B

The following is a summary sheet for estimated capital costs for Option B, where the cost of power production is included.

Option B System Capital Cost Estimate

Major Bio-Energy system components:

			cost	cost fraction
a) site preparation, concrete foundation/floor, standard steel building (50x35)(includes fuel storage)			$87,500	0.103
b) fuel handling, combustion, boiler		145100		
	mechanical installation	12500	157,600	0.185
c) building/plant internal finish, piping, controls			20,000	0.023
d) heat exchangers: plant and IHC				0.000
plant steam-to-hot water		5500		
IHC hot water - to - hot water		1500	7,000	0.008
e) electric power generation			166,000	0.195
f) power line with installation			8000	0.009
e) hot water piping system costs			387,000	0.454
f) hydronic equipment with installation			19600	0.023
Total			**$852,700**	**1.000**

assumptions and notes

1. all analysis is based on an assessment level engineering estimate; further refinements will be made in the actual engineering design work that will include engineering, procurement and installation costs
2. bioplant internal finish includes sprinkler system
3. fuel handling, combustion, boiler system includes exhaust stack

8.5 Monthly & Annual Savings – Option B

In like manner of Option A, the following summary chart shows the savings associated with an Option B scenario. In the production of 10kW power, the system size is larger and a substantial amount of excess heat is produced (about 340%). The negative savings shown on the graph reflect the cost of power production minus the current costs of the replaced grid power and replaced natural gas heat. If future use can be made of the excess heat, the entire operation can be made profitable on a monthly basis.

Option B - heat and 10 kW power production monthly savings and costs

month	monthly hrs	kWh	grid power current cost at $.0727/kWh	power production wood use tons/mo	wood cost at $15/ton	savings at $15/ton
1	744	7440	660	230.8	3461	$565
2	672	6720	596	230.8	3461	781
3	744	7440	660	230.8	3461	-382
4	720	7200	639	230.8	3461	-920
5	744	7440	660	230.8	3461	-1523
6	720	7200	639	230.8	3461	-1907
7	744	7440	660	230.8	3461	-1981
8	744	7440	660	230.8	3461	-1966
9	720	7200	639	230.8	3461	-1911
10	744	7440	660	230.8	3461	-1288
11	720	7200	639	230.8	3461	-840
12	744	7440	660	230.8	3461	325
		87600	7770	2769.0		-$11,048
			0.0887			

assumptions and notes

1. to produce 10 kW, approximately 2769 tons/yr = 230.75 tons/mo are needed this is based on combustion efficiency = 70%, plant heat transfer = 95%, external system heat transfer = 95% efficiency, electric generator = 90% efficiency, parasitic power load (plant power requirements) = 12.5%
2. power price per kWh is based on a blended average of existing Community buildings' usage
3. power production yields "waste" or excess heat approximately 340% above the Taos Community requirements

The following chart shows the savings over a twelve year period with the assumption, as in Option A, that the price of natural gas will go up at approximately 15% per year from the first year's current cost and that electric costs per kWh will increase 5% per year from the first year's current cost.

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Option B Annual Savings and Costs

year	kWh	cost grid	cost nat gas	wood cost $15/ton	savings at $15/ton	cumulative savings at $15/ton
1	87600	7770	22717	41535	-11048	-11048
2	87600	8159	26124	41535	-7252	-18300
3	87600	8547	29532	41535	-3456	-21756
4	87600	8936	32939	41535	340	-21416
5	87600	9324	36347	41535	4136	-17281
6	87600	9713	39754	41535	7932	-9349
7	87600	10101	43162	41535	11728	2379
8	87600	10490	46569	41535	15524	17903
9	87600	10878	49977	41535	19320	37223
10	87600	11267	53384	41535	23116	60339
11	87600	11655	56792	41535	26912	87251
12	87600	12044	60199	41535	30708	117959

22717
0.0887

Assumptions and notes:

1. kWh annual consumption based on 10kWx24x265=87600 kWh

2 current grid power is approx. $.0887/kWh, blended average on buildings with the most complete records plus 5% increase per year over this base

3 natural gas current price $.7136/th is blended average on buildings with most complete records;
cost increases are based on industry estimates of 15% annual increase from year one cost

4. wood price defined to be constant $15 - insufficient data on market forces for wood in the Taos area that could affect price in foreseeable future

In Option B, approximately 14% of capital costs are recovered at the end of 12 years

8.6 Operation & Maintenance – Option B

O&M costs Option B

plant	25	364	$9,100
electric power generation	35	104	3640
materiel			2400
total			$15,140

Assumptions and notes

1. plant maintenance assumes approx. 7hrs/week duty
2, materiel costs typically are $200 per month
3. turbine and all electric power generation assumes approx. 2hrs/week

8.7 Option A and B Subsystem Costs

In this section, a detailed breakdown of costs associated with the major subsystems is presented. The totals are shown in the appropriate categories of the summary sheets shown previously.

Piping Subsystem Costs - Options A and B

Segment	Length ft	cost per foot trench	pipe	fittings	material cost	labor cost	total cost
main line							
P-IHC	570	120	30	6	106020	3200	
P-all other bldgs	1256	120	30	6	233616	3200	
total	1826				339636	6400	$346036
branches from main line							
Util	25	80	15	3	2825		
Agr	51	80	15	3	5763		
BIA	46	80	15	3	5198		
Ro/Re	121	80	15	3	13673		
Temp Hous	40	80	15	3	4520		
Wild	79	80	15	3	8927		
total	362				40906		40906
						total	$386942

assumption and notes:
1. nomenclature P = main plant building
2. "length" means trench length; pipe length is twice this value
2. cost of trench includes all labor
3. cost of labor category is for complete system installation to bring to operations status

Hydronic Equip. Subsystem Costs - Options A & B

Bldg	Peak Heating Btu/h	x1.1 SF Btu/h	offices 50% Btu/h	duct coil unit	cost	garage 50% Btu/h	fancoil unit	cost	cost 2 pumps for 2 zones	total cost
Util	54900	60390	30195	DC23	$635	30195	HV-50H	$1,880	$1,279	$3,794
Ro/Re	123208	135529	67764	DC47	708	67764	HV-70H	2,137	$1,279	4124
Ag	61836	68020	34010	DC23	635	34010	HV-50H	1,880	$1,279	3794
Wild	51475	56623	28311	DC23	635	28311	HV-50H	1,880	$1,279	3794
BIA	106400	117040	58520	DC40	$680	58520	HV-70H	$2,137	$1,279	4096
								total		$19,602

Assumptions:
1. peak heating is February, 2003-2004 values

2. SF = safety factor = 1.1
3. hydronic heating units information supplied by Blue Ridge Company
3. buildings are divided into "office" and "garage" spaces, each with 50% of the peak heating requirement
4. cost includes 8 hrs installer labor per unit @ $50/hr = $400
5. IHC heat exchanger at IHC boiler room with approximately 38gpm water flow with 160F in and 140F out

Option B synchronous electric power generation subsystem cost

Components:		cost
a. Dresser-Rand Model 401RT single stage turbine		
b. 480/3/60 synchronous generator		
c. speed reduction gearbox with integral lubrication system		
d. high/low speed flexible couplings		
e. structural steel baseplate		
f. control panel for basic control/protection functions		
	subtotal	$150,000
g. switchgear		10000
h. installation and operational testing	2 man weeks@$75/hr	6000
	total	$166,000

Assumptions and notes:
1. Components a-f all part of Dresser-Rand budgetary price

Option B - System Electric Line Installation and Hook Up Costs

				item cost	cost
a. line placed in main pipeline trench					
cable	1850 ft	$2.00/ft			$3,700
b. line requiring separate ditch to reach water well buildings					
trenching	1000/ft	1.50/ft		1500	
cable	1000/ft	2.00/ft		2000	3500
c. electric hookup					
	2 man days at $50/hr				800
			total		$8,000

Assumptions and notes:
1. item a reflects cost of power cable only placed in pipeline trench
2. item b reflects cost of power cable and trenching
3. electric cable: 600V, 2 gauge 3 conductor with ground
4. trench is typically 8" wide and 30" deep
5. electric hookup refers to power connection to both the IHC and to the Community water well buildings

8.8 Option C – Heat Supply for IHC Only

In this option, a hot water biofuel heating plant could be located approximately 200 ft to the southwest of the IHC and is designed to supply all of the IHC's heat demand. In addition, the size of the boiler has been maintained at 30 bhp – the size chosen to handle all Community buildings heat load discussed in Option A. This scenario will allow for additional future heat production beyond IHC demand of anywhere from 2 to 3 times for uses (e.g. hothouse gardening) to the east. Wood fuel storage is sized to accommodate a 7 day peak use requirement of 6-8 tons.

The following calculations describe the economics of this option. System cost is estimated to be approximately $194,000. As in Options A and B, we have assumed increases in natural gas prices of 15% annually. This has resulted in a simple payback of 10-11 years, based upon fuel cost savings.

8.9 Option C Costs and Anticipated Savings

Option C: IHC heat only, monthly savings and costs

Month	therms	cost nat gas	wood use tons	wood cost $15/ton	savings at $15/ton
1	2266	$1,586	35.9	$538	$1,048
2	2326	$1,628	36.8	552	1,076
3	1623	$1,136	25.7	385	751
4	1536	$1,075	24.3	365	710
5	1229	$860	19.5	292	568
6	1164	$815	18.4	276	538
7	1081	$757	17.1	257	500
8	1116	$781	17.7	265	516
9	1128	$790	17.9	268	522
10	1520	$1,064	24.1	361	703
11	1439	$1,007	22.8	342	666
12	2171	$1,520	34.4	515	1,004
	18,599	$13,019	294.4	$4,416	$8,603
		$0.7000		15	

assumptions and notes
1. natural gas price of $.700/th is the current IHC rate, from existing bills
2. wood consumption is based on .7, .95, .95 combustion, plant system, and pipe system efficiencies and wood heat content of 5000 Btu/lb = 10 million Btu/ton
3. wood cost @ $15/ton is representative of a calculated rate for community slash pile use and for cost of Taos Pueblo forest thinning operations through the joint BLM-Pueblos Joint Assistance Agreements; see separate spreadsheet for wood cost breakdown

Option C - Heat to IHC System Capital Cost Summary

Bio-Energy system components:		cost	cost fraction
a) site preparation, concrete foundation/floor, standard steel building (20x30)(includes fuel storage), architectural façade and landscaping		$30,000	0.154
b) fuel handling, combustion, boiler	100500		
mechanical installation	12500	113,000	0.581
c) building/plant internal finish, piping, controls		10,000	0.051
d) IHC fittings and heat exchanger		2,500	0.013
e) hot water piping system costs		38,956	0.200
Total		**$194,456**	**1.000**

assumptions and notes
1. all analysis is based on an assessment level engineering estimate; further refinements will be made in the actual engineering design work that will include engineering, procurement and installation costs
2. boiler is 30bhp, peak load = 1MMBtu/hr, capability
2. plant location is approximately 200 ft approximately southeast of the IHC utility area
2. bioplant internal finish includes sprinkler system
3. fuel handling, combustion, boiler system includes exhaust stack
4. piping system is 200ft at $150/ft

Piping Subsystem Costs - Options C

Segment	Length ft	cost per foot trench	pipe	fittings	material cost	labor cost	total cost
main line							

P-IHC	200	120	30	6	37200	1600	38956

assumption and notes:
1. nomenclature P = main plant building
2. "length" means trench length; pipe length is twice this value
2. cost of trench includes all labor
3. cost of labor category is for complete system installation to bring to operations status

O&M costs Option C

	labor rate $/hr	hrs/yr	cost
plant	25	208	$5,200
materiel			1200
total			$6,400

Assumptions and notes
1. plant maintenance assumes approx. 4hrs/week duty
2, materiel costs typically are $100 per month

Option C Annual Savings and Costs

IHC year	therms	cost nat gas	wood cost $15/ton	savings at $15/ton	cumulative savings at $15/ton	
1	18,599	12971	4416	8555	8555	
2	18,599	14917	4416	10501	19055	
3	18,599	16862	4416	12446	31502	
4	18,599	18808	4416	14392	45893	
5	18,599	20754	4416	16337	62231	
6	18,599	22699	4416	18283	80514	
7	18,599	24645	4416	20229	100743	
8	18,599	26590	4416	22174	122917	
9	18,599	28536	4416	24120	147037	
10	18,599	30482	4416	26066	173103	
11	18,599	32427	4416	28011	201114	**payback**
12	18,599	34373	4416	29957	231071	

$0.70 per therm, 2004

Assumptions and notes:
1 natural gas current price $.700/th is current IHC rate, from existing bills
cost increases are based on industry estimates of 15% annual increase from year 1rate
2. wood price defined to be constant $15 - see separate spreadsheet on breakdown

9.0 POSSIBLE CONSTRUCTION TIMETABLE

The following is an estimate of total time required to implement Options A, B or C, from the engineering stage through plant commissioning. These are estimates based upon past experience and assume acceptable weather conditions during construction. Many of the listed items occur simultaneously.

Manufacturing of the boiler, fuel feed delivery, and combustion chamber typically takes 12 to 16 weeks from date of order. Similarly, it takes on average 24 weeks from release for manufacture to delivery of the entire electric power generation package (turbine, generator, controls, etc).

Option A, B and C Construction Schedule	Option A	Option B	OptionC
Engineering	6 weeks	6 weeks	4 weeks
Permits	6 weeks	6 weeks	6 weeks
Site Preparation			
Excavation	3 days	4 days	3 days
Gas	7 days	7 days	7 days
Water	7 days	7 days	7 days
Power	2 weeks	4 weeks	2 weeks
Concrete Foundation	7 days	7 weeks	7 weeks
Steel Building Construction	5 weeks	6 weeks	4 weeks
Firebox/boiler/combustor Equipment Installation	3 days	3 days	3 days
Fuel Handling equipment Installation	5 days	7 days	4 days
Plant			
Electrical	3 weeks	6 weeks	2 weeks
Piping	3 weeks	6 weeks	3 weeks
Controls	2 week	4 weeks	2 weeks
Main Hot water Piping			
trench digging and preparation	3 weeks	4 weeks	3 weeks
pipeline installation	2 week	2 weeks	1 week
Hydronic System Installation for each Building	10 days	3 weeks	1 week
Connection to Buildings	10 days	3 weeks	1 week
Heat Exchangers, pumps, fittings			
IHC	2 days	2 days	2 days
plant	3 days	3 days	3 days
Electric Power Generation			
Equipment installation		2 weeks	
Commissioning		10 days	

Plant Commissioning	2 weeks	2 weeks	2 weeks
Total Construction Time Period	7 months	9 months	6months

10. CONCLUSIONS AND RECOMMENDATIONS

BioEnergy Corporation has investigated and presented 3 very different Options for the use of wood as a renewable fuel to supply heat and power to various buildings in the Taos Pueblo. Option A calls for supplying heat only to all of the buildings mentioned in the body of this report. This option replaces all existing natural gas heating requirements with a wood-fired hot water plant located just to the east of the Utility building. In addition, there is sufficient capability designed into the system (30 bhp) so that an additional 15% added heat load in the future can be supplied by the existing system. There are two main pipeline routes - one that supplies only the IHC and the other that follows a northern course past all of the other buildings, terminating at the New Housing Office location. Based on reasonable assumptions made for the continuing increase in the price of natural gas (estimated in this report to be 15% increase per year over year "zero" and that wood in the greater Taos areas can be acquired at approximately $15/ton, a simple capital cost system payback is approximately 15 years. A significant contributing factor to this lies with the some 66% of the entire system cost that goes to the pipeline system needed to bring the hot water to each building.

Option B calls for the production of 10kW of continuous electrical power to the IHC, or in the case of grid power failure, the option of switching that power to run the Pueblo water well pumps. The electric power is produced with a steam plant that turns a turbine and synchronous generator. The heat by-product from the steam used to generate electrical power is several times (350%) more than the heating requirements of all buildings (as in Option A). The added cost of the turbine-generator equipment and the cost to produce power with wood fuel make this option unattractive from a simple payback point of view.
The production of power on a small scale, reduces the associated efficiencies of the plant and raises the costs of power generation. Power generation at this level is rarely economical unless other factors exist, such as a desire for true energy independence from the existing power grid or a very large heat demand load to satisfy.

Option C illustrates an economically viable choice, given the size of the heat demand load. This option is also scalable, so that it can be increased in size, as needed. Option C would be a dedicated biomass system for the production of heat with a hot water (30 bhp plant) to heat the IHC plus approximately 150-200% additional heat for other future uses. The plant location would be within 200 ft to the Southeast of the IHC so the cost of the piping is approximately 20% of entire system cost – considerably less than for Option A or B scenarios. Simple payback for Option C is just over 10 years. This represents a very typical payback timeline when a system is not burdened with lots of piping costs.

BioEnergy suggests that Option C be considered as an economical alternative, if power generation is not a necessity for the tribe. Wood-fired heating plants of this type use proven technology and equipment that can consistently deliver heat through decades of continuous operation. The Taos Pueblo may also consider this option as a "first phase" project and later choose to expand its size and capability, once there is familiarity with the biomass system.

It is fairly safe to assume that North America will be experiencing supply shortages of natural gas for many years to come. The rising cost of fossil fuels provides a reasonable justification for the consideration of using traditional biofuels when they are readily available in the form of waste wood from mills and thinning operations. According to the extensive study of biomass availability that is a part of this study (see Exhibit A), it is apparent that Taos Pueblo is advantageously located in the midst of a large biomass resource area. This resource virtually guarantees the Pueblo of easy access to wood fuel on a sustainable basis. This Project Plan and Preliminary Engineering Design offers three options for the Pueblo. All of these can be reliably fueled from the various sources identified. Although smaller in size, Option C may represent the most economical choice as a starting point. The system can be enlarged in the future, as the needs of the Community grow. In about a decade of operation the entire system will pay for itself from energy savings and continue to generate very affordable heat for many more years afterward.

Biomass Demonstration Project

Based on funding from a State of New Mexico Clean Energy Grant, a Garn 3200 series wood-fired boiler is being installed at the Red Willow Center to supply heat to the Education Training Building, two commercial-scale greenhouses. And additional capacity for two buildings planned for the future. (A similar Garn unit is being installed at Santa Clara Pueblo to supply heat to 30 residences). This project at the Red Willow Center constitutes a district heating system by virtue of supplying heat to a complex of buildings. The existing Education building has a radiant floor heating system. The Garn boiler will tie into the existing propane-fired boiler and will act as a pre-heater, making it unnecessary for any propane to be used when the Garn boiler/thermal storage tank is supplying sufficient hot water. The use of wood enables the operation of commercial greenhouses during the cold season that would be cost-prohibitive using propane or even natural gas. The use of wood from thinning projects also reduces wildfire risk in Taos Pueblo forests, increases forest health, and creates employment for Taos Pueblo members with a truck and a chainsaw. The installation at the Red Willow Center will serve as a demonstration of how this energy system could be utilized at other locations at Taos Pueblo where natural gas is not available.

The Garn 3200: the heart of a district heating system at the Red Willow Center

The Garn heaters in multiple locations throughout the Pueblo could be managed by a single "fire master" who would be responsible for maintain adequate heat levels in the thermal storage tanks. There are minimal on-going maintenance requirements for these systems; for instance, the water in the storage tank must be treated on a regular schedule to prevent bacteria or corrosion. The use of these biomass heaters in multiple installations creates a job opportunity for one or more persons in the operation of the equipment, and a number of jobs in the supply of small diameter logs for fuel.

The payback on purchase and installation will vary based on displacing propane or lower-cost natural gas. A cord of wood at $100. is equivalent to about 50 cents per therm of energy (100,000 Btu.) Natural gas presently costs about 72 cent per therm. After additional cost of purchase of equipment and labor to operate the boiler, this 22 cents per therm savings is not cost effective. The present price of propane is about $2. per therm. The savings per therm are $1.50, therefore the opportunity is displacing propane use. This is the case at the Red

Willow Center where use of wood will reduce heating costs for two commercial-scale greenhouses from $82./day to around $10./day. Another opportunity would be if five or more residential homes were built in close enough proximity on land where natural gas is not available. As part of meeting new housing needs, Tribal Pueblo housing may be building planned clusters of homes that could be heated utilizing a wood-fired district heating system. This technology would enable these homes to have radiant floor heating controlled by a thermostat. This is the approach that Santa Clara Pueblo is taking by heating 31 homes with a single Garn boiler.

Most clusters of larger tribal buildings are presently served by natural gas and do not presently show an opportunity for substantial savings using wood-fired boilers. However, as domestic supplies of natural gas are depleted, the cost of imported liquefied natural gas will make the price rise higher than present price. (See price projections below) By using wood, which can remain at a constant cost because the Pueblo owns it, there is protection against rising costs of natural gas. The expenditure of tribal funds to purchase wood from tribal businesses/resources and to pay someone to maintain and operate Garn boilers are funds that otherwise would go to energy companies, and therefore becomes a local economic benefit. It would mean keeping dollars circulating in the local Taos Pueblo economy.

If natural gas rises above $1.35 a therm, then the use of these wood-fired boilers to supply heat becomes attractive even for tribal buildings supplied by natural gas. At the present trend line of 14% per annum increase in the price of natural gas; the price of $1.35/therm will be reached in five years. Indeed, the price of natural gas has risen 28% per year in the last three years, at which rate the $1.35/therm will be reached in 2 1/2 years.

Case Study of Indian Health Service Clinic

The Health Clinic on Goat Springs Rd. uses over 18,000 therms of gas per year and will cost $24,300 per year to heat if natural gas rises to $1.35 a therm. A wood-fired system would require 120 cords to supply the equivalent amount of heat*. If a cord costs $100. then the 120 cords would cost 12,000. resulting in a $12,300 a year reduction in fuel costs. Assuming labor costs of $7,800. per year ($30. /day to fire the boiler two hrs. for 260 days of the year), and $500. for parts, the annual cost of operation would be $8,300. The amount available then to pay for the Garn would be $4,000. a year ($12,300 -$8,300 O & M cost). A Garn 3200 costs about $50,000 including piping and containment structure with pumps and controls. The simple payback period then would be 12 1/2 years ($50,000/$4,000.= 12.5) The boiler can have a life cycle of at least 20 years, yielding a savings of $30,000. over the remaining 7 1/2 years. If purchased through a loan with interest at 7 %, the payback period would be 20 years. There are Garn boilers in the field that are over 30 years old and still operating. More importantly, the earnings from wood sales and the job firing the boiler which would be 20 years x $7,800 labor + $12,000 wood =$396,000. The avoided price of $1.35 per therm of natural gas is the breakeven point for paying back the cost of the Garn boiler with interest, with the earnings in job creation and wood sales realizing a sizable net benefit.

*(Assumption: Air-dry wood valued at 12,000,0000 BTU/ton @ 84% conversion efficiency) A cord is estimated to be 1.5 tons)

“ Option C “ in the BioEnergy Corp. pre-engineering study above also would supply heat to the Health Clinic but with a twofold surplus that could used to supply heat to a planned apartment complex and/or to a complex of commercial greenhouses.

The photo below is of a boiler in Nederland, Colorado that was installed by BioEnergy Corp., the company that completed the preliminary engineering study for the district heating system layout shown above. A similar type of boiler could be used to supply heat to the Health Clinic area as part of “Option C”. It would require about 3 tons a day to supply heat to this district. The boiler requires chipped wood, which is fed into the boiler by an automated auger and belt system. This system is much more automated than the Garn 3200.

Electric power can be produced as well from the steam (10 kW capacity generator), but the fuel requirements increase to 7 tons/day, and the economics are not attractive.

Potential District Heating Locations and Annual Wood Fuel Requirement

● Taos Pueblo Day School/Head Start, Community Center, Health and Social Services
80 tons or 54 cords (8,000 therms natural gas equivalent)

● Spider Rock Rd./Goat Springs Rd area T.P/ Picuris Health Clinic, T.P. Utilities, Realty/Roads, Forestry, Wilderness, Housing, planned apartments (A Project Plan and Preliminary Engineering Design Study for this area is included as an attached document to this study) 377 tons or 250 cords wood/year (32,000 therms nat. gas)

● Law Enforcement, Fire station, Senior Center, Environmental Office, Tribal Offices
51 tons or 34 cords * (5,100 therms nat. gas)

● Recreation Center, Pow-wow ground area
306 tons or 204 cords ** (30,600 therms nat. gas)

*(Assumption: 10,000 sq. ft., 7,000 HDD, 51,000Btu/sq.ft.

** (Assumption: 34,000 sq. ft. 7,000 HDD, 90,000 Btu/sq. ft.

It would require 814 tons or 542 cords annually to supply all four district heating systems. The assessment in the baseline resource assessment above indicates 2,475 air-dry tons a heating season available from Taos Pueblo forests on a perpetual (sustainable) basis. Therefore, the 814 tons to supply these combined heating systems would represent about a third of the 2,475 annual supply. The economic development benefit over 20 years, based on figures generated in the example of the Health Clinic case above, would include $1,084,000. for wood and $624,000. for fire attendant. If the boilers last an additional 10 years, then another $894,000. in economic development earnings will bring the total benefit to $2.6 million or $86,733. a year.

However, these are estimates that are based on natural gas rising to $1.35 therm in 3 to 5 years and then leveling out. The total natural gas/propane use for the building complexes above (including planned recreation center) is 95,700 therms. If the price continues to rise at an annual rate of 14%, then the present cost of $67,947 per year at 71 cents per therm will become by 2015 $268,917. annually. This is the disturbing future of dwindling supplies of fossil fuels. Senator Bingaman is on the record as Chairman of the Senate Energy Committee that by the end of the decade we will have to import most of our natural gas at a higher cost. This the reason why wood resources along with solar and ground source geothermal will need to play an increasing role in building design to enable Taos Pueblo to afford heating large public buildings.

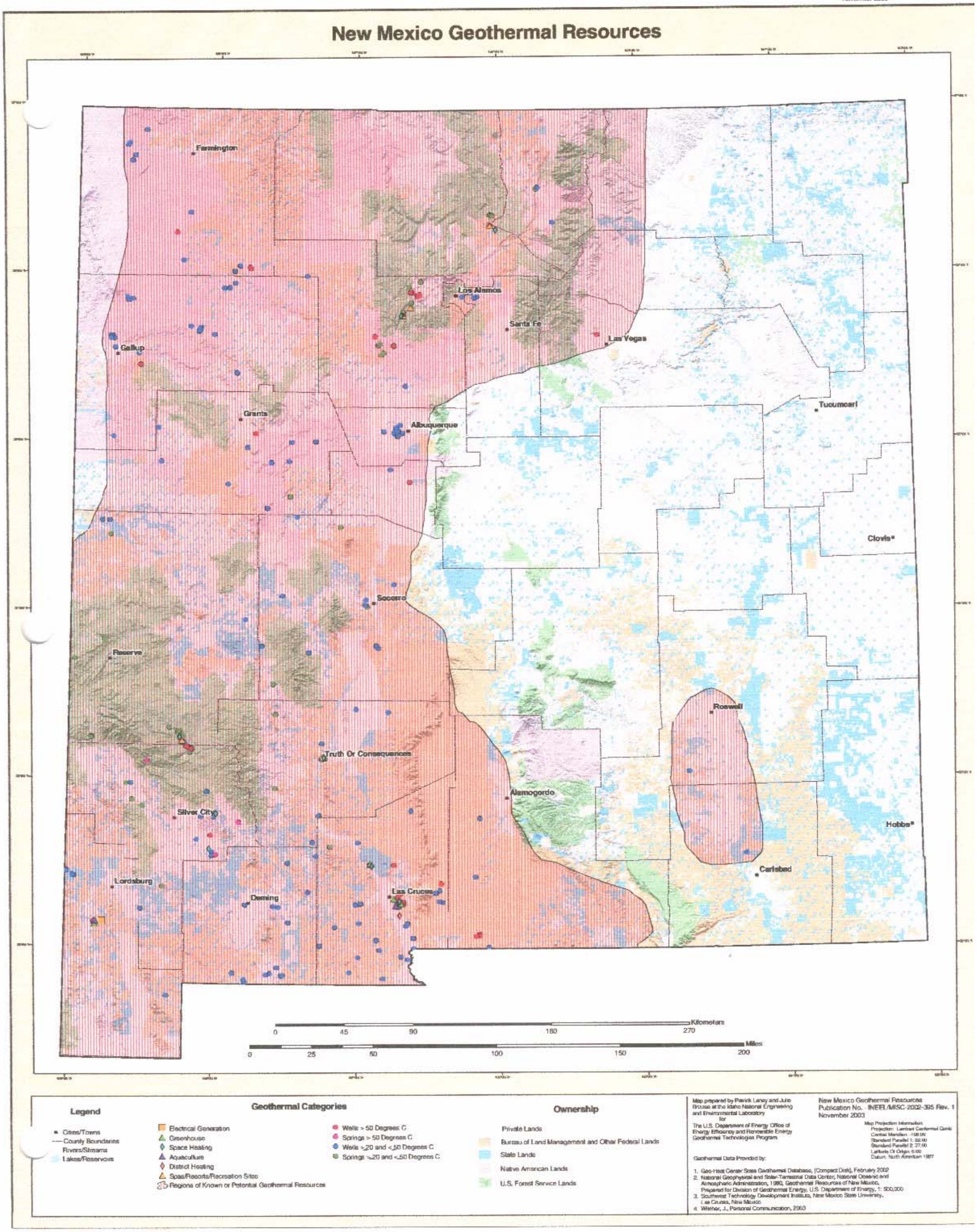
GEOTHERMAL

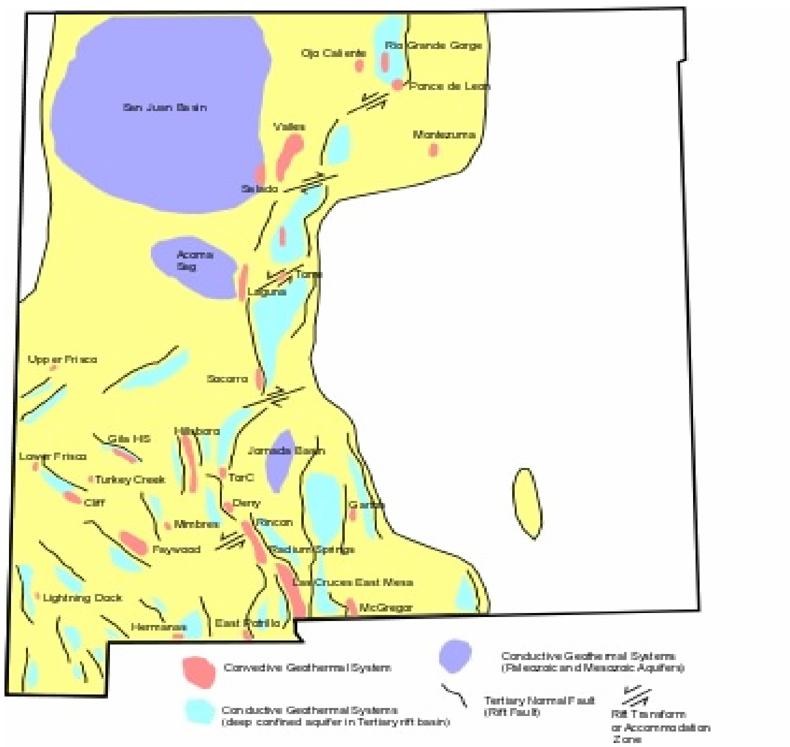
A. Baseline Resources

The two maps below shows that Taos Pueblo is located in an area of potential geothermal resources. The presence of the Manby Hot Springs less than three miles from the northern boundary of Tract A suggests that there may be some potential in that area. However, any kind of commercial scale development, even several miles away, could adversely affect this recreational spot. This merits further investigation to determine if areas within Tract A may have hot water resources like Manby Hot Springs, but do not reach the surface. There are no apparent geothermal resources for electrical generation.

There is also anecdotal information from an older tribal member that when a child he saw "hot" water seeping from the ground in the area above the Health Clinic. Site-specific research would be necessary to determine if there is any potential in these areas.

The more certain and pervasive geothermal resource is the constant warmth of the ground at depths below four feet relative to the air temperature during the heating season. The fact that water pipes need to be buried 4 feet here to avoid freezing is an example of this "warmth". This temperature is around 55 degrees and due to the extremely low temperatures during the winter at Taos Pueblo, this ground warmth becomes a resource that is available under and near any structure no matter where it is located. Whereas the amount of wood that can be harvested on a sustainable basis is finite, there is a limitless resource of ground heat to heat any number of structures that could be built at Taos Pueblo.


New Mexico Geothermal Resources
Farmington
Los Alamos
Santa Fe
Las Vegas
Gallup
Grants
Albuquerque
Tucumcari
Clovis
Socorro
Reserve
Roswell
Truth Or Consequences
Alamogordo
Silver City
Hobbs
Carlsbad
Lordsburg
Deming
Las Cruces
Kilometers
0 45 90 180 270
Miles
0 25 50 100 150 200
Legend
Cities/Towns
County Boundaries
Rivers/Streams
Lakes/Reservoirs
Geothermal Categories
Electrical Generation
Greenhouse
Space Heating
Aquaculture
District Heating
Spas/Resorts/Recreation Sites
Regions of Known or Potential Geothermal Resources
Wells > 50 Degrees C
Springs > 50 Degrees C
Wells >20 and <50 Degrees C
Springs >20 and <50 Degrees C
Ownership
Private Lands
Bureau of Land Management and Other Federal Lands
State Lands
Native American Lands
U.S. Forest Service Lands
Map prepared by Patrick Laney and Julie Brizzee at the Idaho National Engineering and Environmental Laboratory
for
The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Geothermal Technologies Program
Geothermal Data Provided by:
1. Geo-Heat Center State Geothermal Database, [Compact Disk], February 2002
2. National Geophysical and Solar-Terrestrial Data Center, National Oceanic and Atmospheric Administration, 1980, Geothermal Resources of New Mexico, Prepared for Division of Geothermal Energy, U.S. Department of Energy, 1: 500,000
3. Southwest Technology Development Institute, New Mexico State University, Las Cruces, New Mexico
4. Witcher, J., Personal Communication, 2003
New Mexico Geothermal Resources
Publication No. - INEEL/MISC-2002-395 Rev. 1
November 2003
Map Projection Information
Projection: Lambert Conformal Conic
Standard Parallel 1: 32.00
Standard Parallel 2: 37.00
Datum: North American 1927



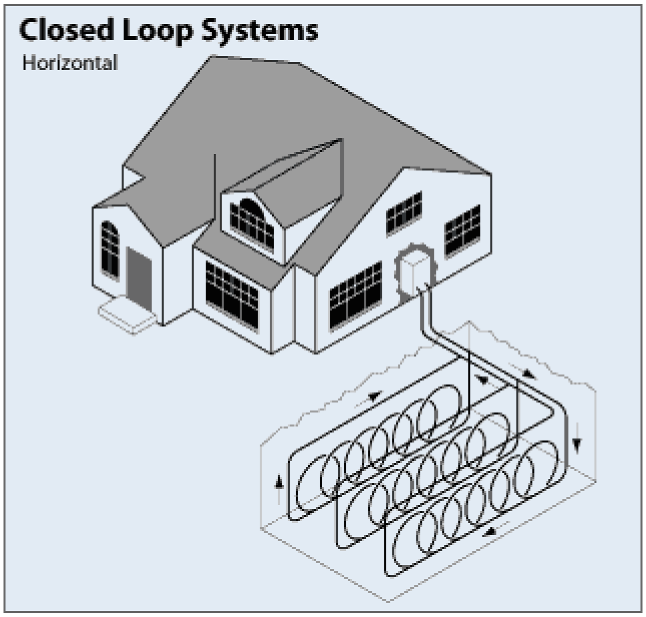
New Mexico geothermal resources. Yellow indicates region with inferred geothermal resource potential based on heat flow information and well bottom hole temperatures. Witcher, A STRATEGIC PLAN FOR NEW MEXICO GEOTHERMAL RESOURCES DEVELOPMENT, DOE, 2004

B. TECHNICAL RESOURCES

Ground-Coupled Heat Pumps

Ground-source heat pumps use the earth or groundwater as a heat source in winter and a heat sink in summer. The heat pump, a device that moves heat from one place to another, transfers heat from the soil to the building in winter and from the building to the soil in summer. The rate of installation in the U.S. is thought to be between 10,000 and 40,000 per year. (Geo-heat Center, Oregon) The systems are in wide use in Canada and are very effective in a climate similar to that of Taos Pueblo at 7,000 ft.

A system can either use horizontal piping in a series of trenches, or can be vertical holes that can be 100 to 150 feet deep. They can either be open, meaning that the water table is used as a reservoir of 55-degree water, with the uptake pipe at one location, and the return pipe at another. Or the system can be "closed", meaning that a fluid such as antifreeze or water is in closed loop of piping.



C. LOAD DESCRIPTION AND ECONOMIC ANALYSIS

There are high initial costs of installation due to the drilling or trenching required Due to the high initial costs, ground source geothermal would only be practical for large loads at Taos Pueblo such as a casino, recreational center, health clinic, or schools that have large enough budgets with reasonable predictability over time. . However, the ground systems are rated to last 50 years and with natural gas at 70 cents a thermo, payback can be in 12 to 15 years. As natural gas prices near 1.00/therm the economics of these systems become interesting because the payback period is then in the range of 8 to 10 years.

HYDROELECTRIC

A. BASELINE RESOURCE

There are three natural watercourses that are on Taos Pueblo lands that have hydroelectric potential. These are the Rio Lucero, Rio Pueblo and the Rio Grande. There are also artificial waterways – irrigation piping- that have hydroelectric potential. There is planning presently underway by HKM Engineers of Billings Montana to rehabilitate the irrigation system with pressurized pipes and this is where the hydroelectric opportunity is created. HKM has completed a hydroelectric feasibility study for Taos Pueblo identifying the location and size of turbines that could be integrated into the irrigation system. The complete study may be found in the appendix and will show the baseline resources available in the irrigation flows during the irrigation season.

The average monthly flows are of the highest importance in assessing hydroelectric turbine size potential because it shows the seasonal extremes of low flow and peak flow. Diversion of 20% of flow for a run-of the-river hydroelectric turbine is possible without negative impacts on biotics. Therefore the hydroelectric resource potential is essentially the 20% flow rate. The flow of the Rio Pueblo above the village was not considered due to traditional uses.

Rio Lucero Above Tenorio Tract Diversion Dam

Monthly mean stream flow, in ft^3/s (cubic feet per second)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean of monthly stream flows	5.99	6.00	9.15	21.8	58.1	69.5	29.8	18.1	13.5	11.4	8.98	7.18

Note: One cubic feet per second equals about 450 gallons per minute or 27,000 gallons per hour

	20 % of Monthly mean stream flow, in ft^3/s (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean of monthly stream flows	1.2	1.2	1.8	4.7	11.6	14	6	3.6	2.7	2.3	1.8	1.4

Rio Pueblo Below Los Cordovas

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean of monthly Discharge	31	36	47	107	243	132	28	23	22	25	31	32

Monthly mean in cfs (Calculation Period From:1957-04-01, To: 2005-09-30)

Rio Pueblo Below Los Cordovas at 20% Flow

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
20% of monthly Discharge	6.2	7.2	9.4	21.4	48.6	26.4	5.6	4.6	4.4	5	6.2	6.4

Monthly mean in cfs (Calculation Period From: 1957-04-01, To: 2005-09-30)

Rio Grande Near Arroyo Hondo*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean of monthly Discharge	427	490.	661	763	1,290	1,480	711	373	316	350.	503	428

Monthly mean in cfs (Calculation Period From: 1963 To:2004 USGS

*Data from this gage most accurately represents flows on Taos Pueblo lands; the gage below Taos Junction Bridge would be misrepresentative due to tributary flows from the Rio Pueblo

The flow rates above need to be divided by 2 because the western boundary of Taos Pueblo lands is the middle of the Rio Grande. Therefore it must be considered that only half of the river flow could be utilized.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean of monthly Discharge	213.5	245.	330.5	381.5	645	740	355.5	186.5	158	175.	251.5	214

Note: The baseline resources of water flows in irrigation piping is included in the HKM Engineering Study section.

Topography/Hydraulic Head and Technical Generation Potential

Elevation change in a river or stream course is what determines the opportunity for static hydraulic head in a run-of-the-river diversion. This hydraulic head combined with the rate of flow is what determines the rough electrical generation potential for a particular reach or length of the water course. A major limiting factor in any diversion of water is impact on the plants and animals in the stream course. A general rule of thumb is that a 20% of flow diversion is possible without any impacts that would be different from seasonal fluctuations. In times of drought the amount of diversion could be reduced or stopped. Some locations are culturally inappropriate such as the Rio Pueblo above the Village. Any diversion may be considered an inappropriate impact on the scenic values of an area; however these can be reduced to a great degree.

There are two locations that have dramatic elevation changes combined with adequate flows. However, these are rugged, difficult terrains that will not allow for use of heavy equipment. Therefore, pipe size is limited to what can be carried by men or horse, or by what can be delivered by helicopter. The pipe will not be able to be buried in trenching due to lack of bringing heavy digging equipment into these areas. Thrust blocks would have to be built where natural rock formations did not serve this function. The pipe can be protected from sun and insulated to some degree with a mounding of soil, rocks and bark. This strategy would also camouflage the pipe from any visual or scenic impacts. The two locations that have substantial elevation change are;

A. Rio Lucero above the Indian Ditch diversion dam
Length 2.1 miles Elevation Change 738ft. Dynamic Head 690 ft.*

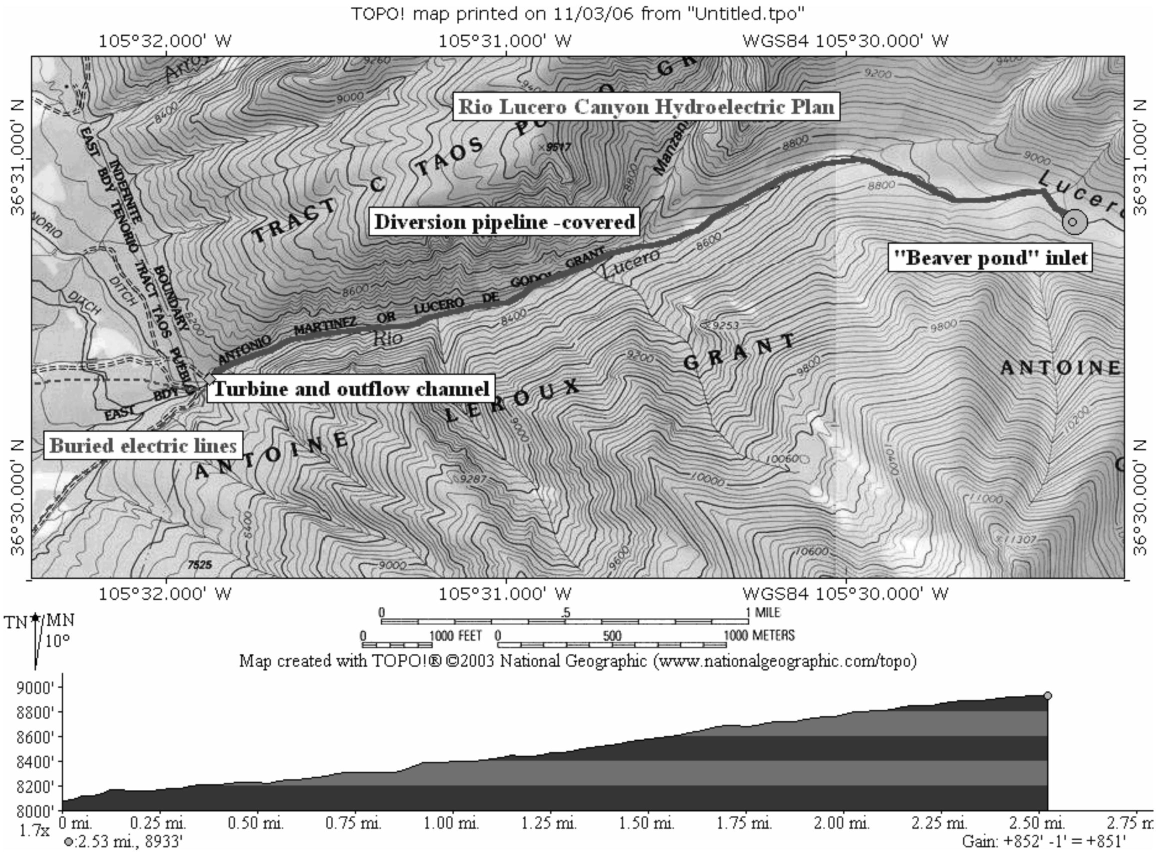
B. Rio Pueblo descending into Rio Grande Gorge
Length 2.8miles Elevation Change 490 ft. Dynamic Head 440 ft.
* "dynamic head" includes friction losses in pipes

Rio Lucero at Indian Ditch Diversion

	20 % of Monthly mean stream flow, in ft^3/s (cubic feet per second)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean of monthly stream flows	1.2	1.2	1.8	4.7	11.6	14	6	3.6	2.7	2.3	1.8	1.4

The chart above indicates that the average of the 20% of annual flow is 4.3 cfs. The maximum generation potential would be 96 kW. In order to deliver 4.3 cu. ft. sec., or 3,600 gal. / min. a pressurized pipe 14" in diameter would be required. A 20 foot section of 14" pvc pipe will weigh about 500 lbs. and would need to be carried by eight men much like a viga, or dragged/carried by horses. However this will increase costs. It would be practical to divert no more than 2 cfs using a 10" diameter pipe.

The inflow for the pipe is created by a weir or log dam across the stream that would create a pond deep enough to fill the 10" diameter pipe. This would suggest a depth of 3 or 4 feet to keep the intake clear of mud, rocks and debris on the pond bottom. This intake pond would most likely become a good fishing site! A head gate valve would allow for closing the pipe during the winter. An intake screen would keep debris and fish from the pipe, and protect the turbine from any damage.



Hydro Potential on Rio Lucero

Assuming 14.5 cu.ft./sec. which is half of annual flow of Rio Lucero, and assuming 600 ft. head, the average electrical generation would be 444 kW capacity. Assuming availability of 8322 hours in the year, annual generation would be 3,692,471 kWhr. This power could be: A. utililzed directly by "loads" at Taos Pueblo to offset amount o
f power purchased from Kit Carson, or B. the power could be sold to Kit Carson Electric.

A. Using the residential rate of $.0782/kWh (7.82 cents) charged by Kit Carson Electric for peak use, and the $.0420/kWh (4.2 cents) rate for off-peak, and combining these rates in a 2 to 1 ratio yields the weighted rate of $.066 kWh (6.6 cents)The commercial rate is $.069/kWh (6.9 cents). Therefore, the potential 3,692,471 kWh generated annually would have a gross annual value of $243,703 for residences, and $ 254,780. for commercial. At today's rates, over 25 years this hydro facility would produce $6,092,577 worth of residential electricity, or $6,369,512. worth of commercial electricity.

	Flow (cu.ft./sec.)	Head (ft.)	Efficiency	Constant	Power (kW)	Availability	Annual kWh
January	3	600	0.6	0.085	92	685	62,883
February	3	600	0.6	0.085	92	685	62,883

March	4.6	600	0.6	0.085	141	685	96,421
April	10.9	600	0.6	0.085	334	685	228,475
May	29	600	0.6	0.085	887	685	607,869
June	34.8	600	0.6	0.085	1,065	685	729,443
July	14.9	600	0.6	0.085	456	685	312,319
August	9	600	0.6	0.085	275	685	188,649
September	6.75	600	0.6	0.085	207	685	141,487
October	5.7	600	0.6	0.085	174	685	119,478
November	4.49	600	0.6	0.085	137	685	94,115
December	3.59	600	0.6	0.085	110	685	75,250
							2,719,271

Flow rates based on USGS records, 1913 to present

Lower Rio Pueblo Below Los Cordovas

Rio Pueblo Below Los Cordovas at 20% Flow (cfs)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6.2	**7.2**	**9.4**	**21.4**	**48.6**	**26.4**	**5.6**	**4.6**	**4.4**	**5**	**6.2**	**6.4**

Monthly mean in cfs (Calculation Period From:1957-04-01, To:2005-09-30 USGS

Potential on the Lower Rio Pueblo

There exists a very rapid elevation change where the Rio Pueblo descends into the Rio Grande gorge and enters the Rio Grande near Taos Junction bridge, dropping 390 feet in 1.3 miles. A "run-of-the-river" hydroelectric installation could be implemented that would divert a percentage of the stream flow into a pipe that would then run somewhat parallel to the river and re-enter the river after enough of a drop in elevation to create "hydraulic head" adequate for electrical generation. The hydroelectric turbine housed in a small structure would be at the point of re –entry into the Rio Pueblo (within 300 yards of the Rio Pueblo entering the Rio Grande. The power generated could be interconnected to the Kit Carson grid on a 25 kV line that traverses Tract A within two miles of the potential turbine location. Or the power could be used directly at the very scenic lookout on the peninsula of land at the southeast extremity of Tract A. The Rio Grande gorge rim has potential for eco- tourism development with overnight lodging such as yurts or adobe casitas with excellent access to fishing, hiking, and swimming on the lower Rio Pueblo and Rio Grande. If buffalo, big horn sheep and antelope are introduced into the area by Taos Pueblo that would be an additional interest for visitors. This area can be viewed as the "Grand Canyon of New Mexico", and can be developed for eco-tourism in a sensitive way without compromising the environment for eagles, raptors, and other wildlife. Indeed, the lower Rio Pueblo is a popular fishing area and any hydroelectric project would have to be constructed in a fashion that camouflaged or covered the piping so as not to be seen. The structure housing the turbine could be built from native rock and have minimal impacts on the scenic area. There are campground shelters and a large bridge over the Rio Grande nearby, so it is not pristine wilderness at this particular location.

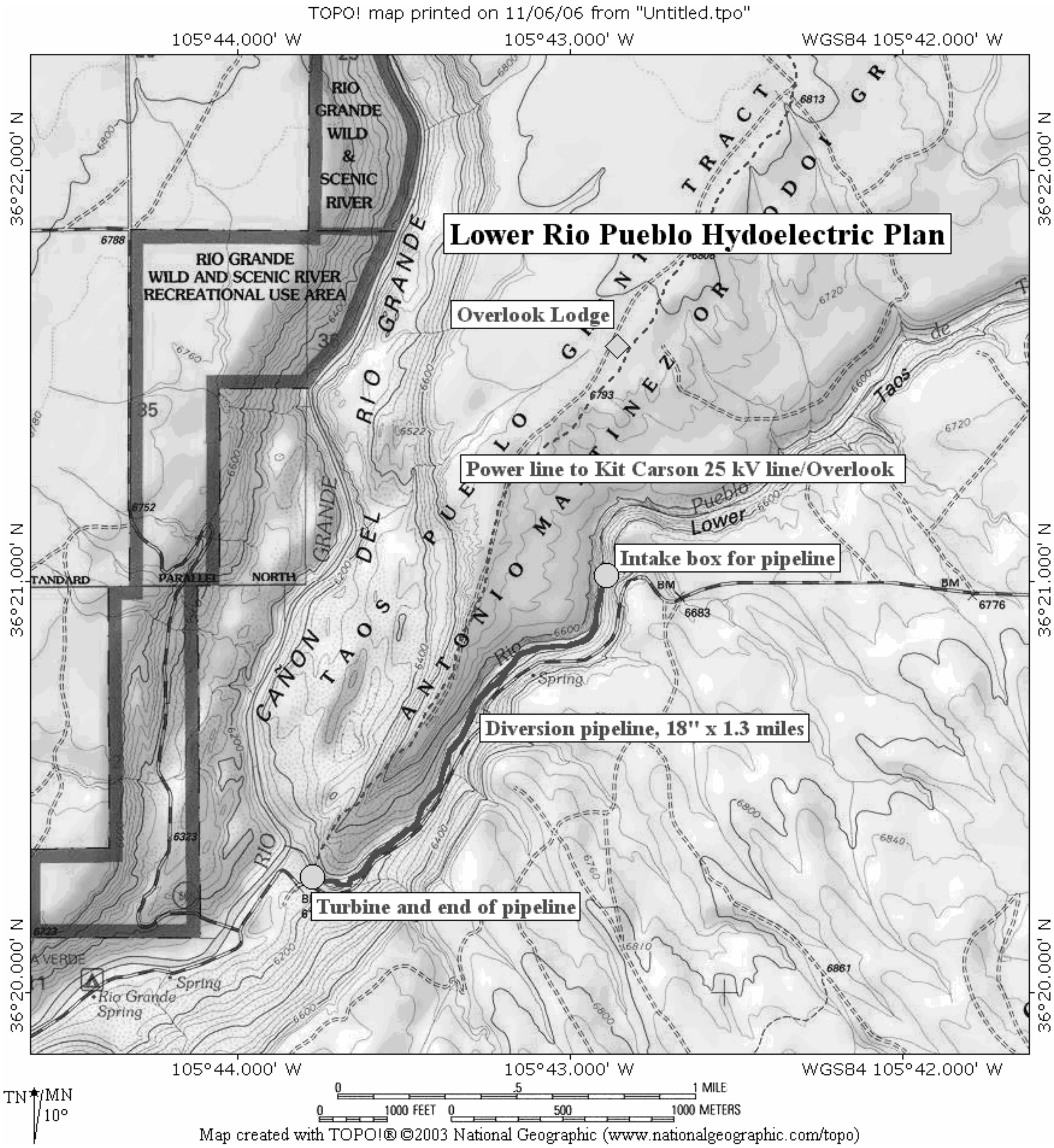
Based on 44 years of stream flow data from a USGS gauge on the Rio Pueblo at Los Cordovas, the stream flow ranges from an average of 22 cfs in September up to 243 cfs in May, with an annual average of 59 cfs. It is considered acceptable in general to divert up to 20% of flow of any watercourse without causing any impacts on the biotics in the river system. This is because there are natural swings in the amount of any stream flow from year to year that can occur without causing life-threatening impacts. Therefore 12 cfs would be the amount of water available for hydroelectric generation.

A pipe or penstock traversing 1.3 miles of the lower Rio Pueblo will realize a 390' elevation change. Accounting for pipe friction losses, the dynamic head would be 350'. Diverting 10 cubic feet per second of water would power a 180 kW turbine and producing over 1 million kilowatt-hours annually.

HydroElectric Potential on the Lower Rio Pueblo

There exists a very rapid elevation change where the Rio Pueblo descends into the Rio Grande gorge and enters the Rio Grande near Taos Junction bridge. A "run-of-the-river" hydroelectric installation could be implemented that would divert a percentage of the streamflow into a pipe that would then run somewhat parallel to the river and re-enter the river after enough of a drop in elevation to create "hydraulic head" adequate for electrical generation. The hydroelectric turbine housed in a small structure would be near the point of re –entry into the Rio Pueblo. The power generated could be interconnected to the Kit Carson grid on a 25 kV line that traverses Tract A within two miles of the potential turbine location. Or the power could be used directly at the very scenic lookout on the peninsula of land at the southeast extremity of Tract A. The Rio Grande gorge rim has potential for eco- tourism development with overnight lodging such as yurts or adobe casitas with excellent access to fishing, hiking,and swimming on the lower Rio Pueblo and Rio Grande. If buffalo, big horn sheep and antelope are introduced into the area by Taos Pueblo (under consideration bythe WarChief office) that would be an additional interest for visitors. This area can be viewed as the "Grand Canyon of New Mexico", and can be developed for eco-tourism in a sensitive way without comprimising the environment for eagles and raptors.

Based on 44 years of streamflow data from a USGS guage on the Rio Pueblo at Los Cordovas, the streamflow ranges from an average of 22 cfs in September up to 243 cfs in May, with an annual average of 59 cfs. It is considered acceptable to divert up to 20% of streamflow without causing any impacts on the biotics in the river system. Diverting 20% of minimum annual flow, which is 22 cfs in September, would allow, use of 4.4 cfs for power generation . Utilizing a 300' elevation change in a 3/4 mile stretch of the Rio Pueblo would yield 70 kW generation. Diverting up to 10 cfs, which is less than 20% of the average annual flow of 59 cfs, would generate 153 kW.



155 kW Turbine and 300' Hydraulic Head

	Flow (cfs)	Head (ft.)	Efficiency	Constant	Power (kW)	Availability	Monthly kWh
January	6.48	300	0.6	0.085	99	685	67,914
February	7.46	300	0.6	0.085	114	685	78,185
March	10	300	0.6	0.085	153	685	104,805
April	10	300	0.6	0.085	153	685	104,805
May	10	300	0.6	0.085	153	685	104,805
June	10	300	0.6	0.085	153	685	104,805
July	5.8	300	0.6	0.085	89	685	60,787

August	4.78	300	0.6	0.085	73	685	50,097
September	4.44	300	0.6	0.085	68	685	46,533
October	5.2	300	0.6	0.085	80	685	54,499
November	6.48	300	0.6	0.085	99	685	67,914
December	6.68	300	0.6	0.085	102	685	70,010
							915,157

IRRIGATION – BASED HYDROELECTRIC

PUEBLO OF TAOS HYDROPOWER GENERATION ALTERNATIVES

PREPARED FOR

RENEWABLE ENERGY OFFICE OF TAOS PUEBLO

PREPARED BY

HKM ENGINEERING

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NOVEMBER 2006

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PUEBLO OF TAOS HYDROPOWER GENERATION ALTERNATIVES

Introduction

The Renewable Energy Office of Taos Pueblo requested HKM Engineering Inc. to evaluate the hydropower potential associated with delivering water through irrigation pipelines proposed by the Tribe to be built as part of their water rights settlement. There are conceptual Irrigation Rehabilitation Plans developed for both the Rio Lucero and Rio Pueblo de Taos watersheds. These plans identify that a major number of expensive pressure reducing valves are required for energy dissipation. In lieu of dissipating the energy, this study will analyze the opportunity to hydroelectric generation. Further, there is also an initial plan developed for recharging the Buffalo Pasture in the Grant area, which could also be adapted for power generation purposes.

Conceptually, each of the noted plans could be modified so that certain reaches of the irrigation or recharge pipelines could be used as penstocks for hydroelectric generation. The pipelines will be sized to meet peak daily irrigation or recharge demands. The best alternatives are irrigation projects associated with major service areas (maximize water supply) and significant elevation changes. Efforts were also made to site turbines in the vicinity of existing power networks. A review will be made of the potential for generating electricity during the winter season to increase project feasibility. Conceptual strategies are proposed for returning winter diversions back into the river courses or to assist in recharging the Buffalo Pasture.

The negotiated water settlement identifies the baseline parameters upon which water can be diverted from the Rio Lucero and Rio Pueblo de Taos under current stream allocation rules. There are also procedures or agreements identified in the settlement that could be used to enable the Pueblo to markedly increase diversions during the winter and non-peak irrigation season. Results will be presented for a baseline case and a maximum case in this analysis.

Appraisal level capital costs for the turbines, steel pipelines (penstocks), and related hydroelectric equipment will be estimated for specific development alternatives. Such costs will be compared against the estimated costs of the pressure release values being proposed for the irrigation rehabilitation projects.

The following sections of this report identify candidate projects which exhibit varying degrees of hydropower development potential. Contact was made with the Bureau of Reclamation Power Division, Great Plains Region, and some private small hydropower project developers to obtain general guidelines for project feasibility. See Appendix F for details.

Rio Lucero Watershed

The "Taos Pueblo Irrigation Rehabilitation Plan for Rio Lucero Region" presents two significant irrigation projects, which serve about 2000 acres of land. This preliminary hydropower project analysis will separately evaluate the potential of hydroelectric generation associated with both the Indian and Tenorio ditch systems.

Indian Ditch Project

Baseline Case

<u>Overview</u> Figures 1 and 2 present the basic components of the proposed multi-purpose irrigation and hydroelectric projects. The elevation difference between the point of diversion and Turbine E is 870 feet. There are significant head differences between all the proposed turbines. Of the 1120-acre Indian Ditch service area, only 210 acres are located above Turbine B. These lands will require a separate dedicated irrigation only pipeline. The rest of the available water supply can, therefore, be used to first generate power and then be released to dedicated irrigated only service networks. This allows the penstock pipeline to serve multiple purposes and develop greater overall benefits to the Pueblo. Winter flows will be discharged from Turbine C and directly into the Rio Lucero.

Water supply estimates used for power generation calculations were developed using the following criteria:

1. Study Period: 1935 – 1988 (Use USGS natural flow gage)
2. Rio Lucero Decree Allocation: 46.7%
3. Indian Ditch Allocation: 56.0% of 46.7%
4. Diversion Capacity: 20.3 cfs (peak day (0.28 inches) for 1120 acres @ 65% efficiency)
5. Winter Flows: All allocated flow goes to Indian Ditch
6. Maximum Flows: Available flows capped at pipeline capacities for all months
7. Shortages: Irrigation shortages shared at all service areas
8. Excess Flows: Routed to Turbine E because of higher head
9. Winter Return Flows: Winter flows are returned back to the Rio Lucero at Turbine C to assist in recharging the Buffalo Pasture

Table 1 in Appendix A summarizes the results of the water supply study. This tabulation documents the water delivered to each turbine for each month during the 1935-1988 study period, based on the criteria noted above. Under the settlement, Taos Pueblo can acquire water rights and, therefore, increase the percentage of water that can be diverted from the Rio Lucero. As such, power generation potential can be correspondingly increased in the future as the Pueblo increases their decree allocation.

<u>Power Generation</u> An additional spreadsheet was completed for each turbine studied to calculate the power generation (kWh) for 1935-1988 (See Tables 2-6 in Appendix B). The individual turbine flows in CFS were calculated from the power water supplied (acre-feet) to each turbine determined by the methods described above. The head in feet for each turbine was determined, the turbine efficiency utilized was 70 percent, and the power constant of 0.085 was utilized to obtain generation in kW. After the generation was determined, the operating time was calculated at 95 percent per month operational time in hours, and the kW generation multiplied by the operating hours resulted in total turbine generation in kWh for each month of the study.

Figure 1 Indian Ditch Hydropower Concept, Rio Lucero

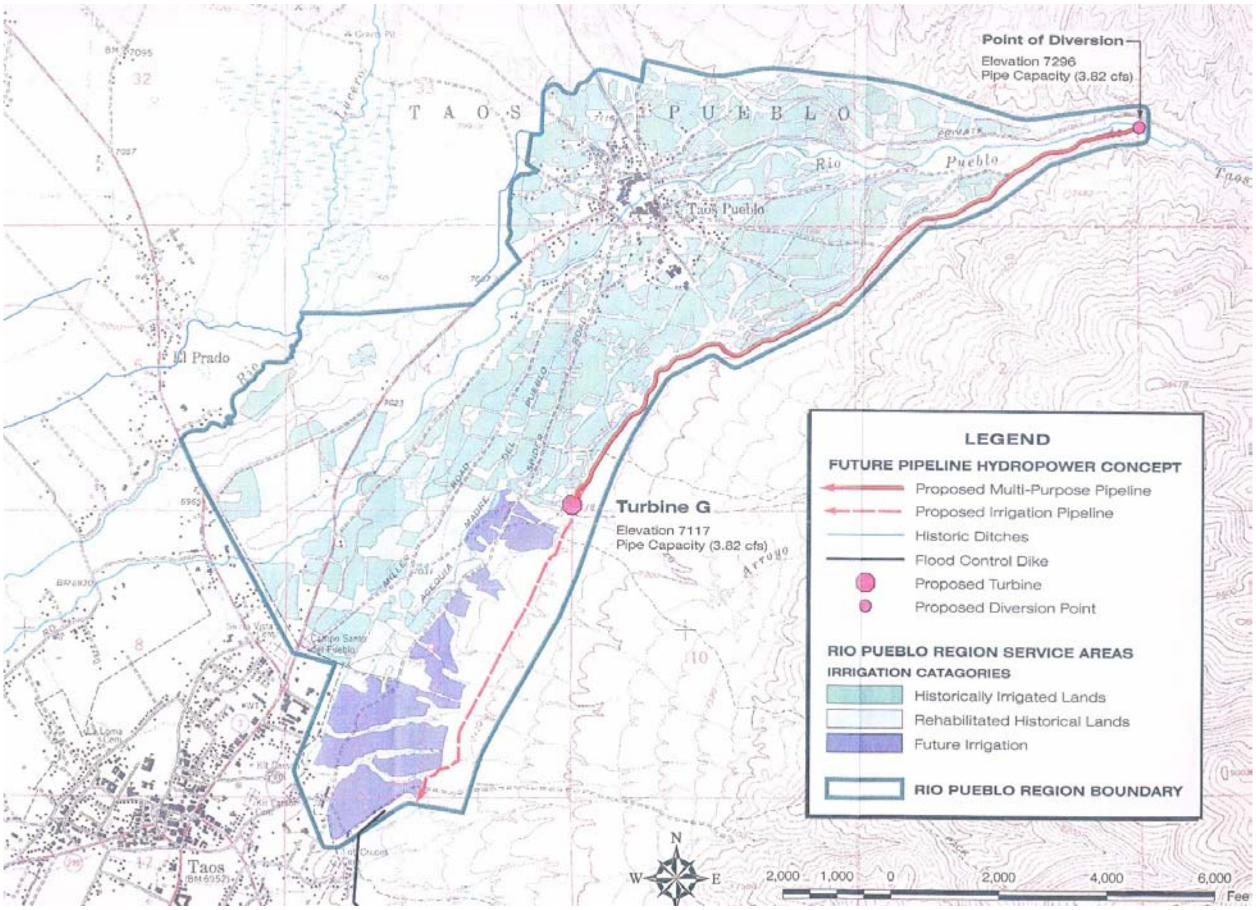
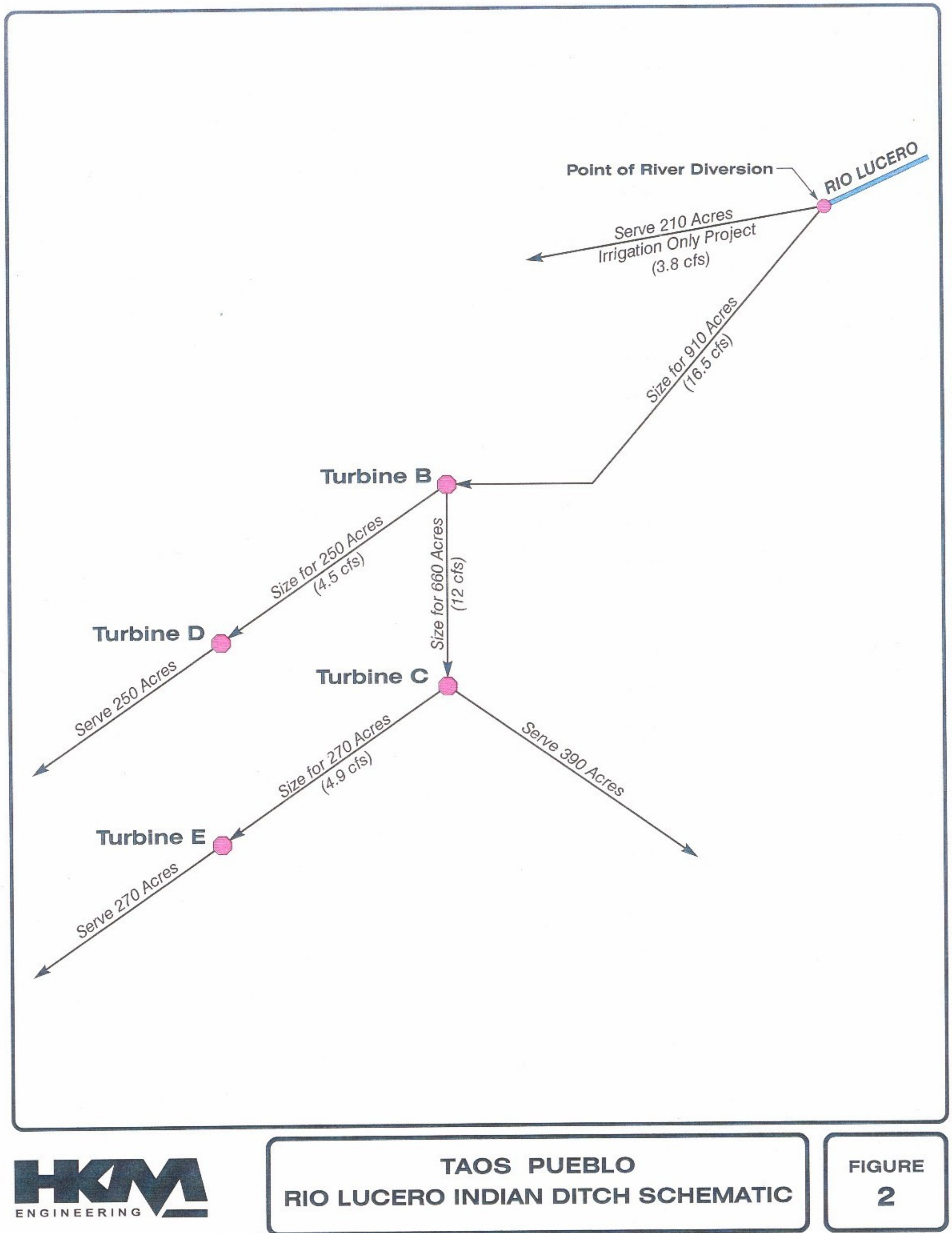


Figure 2 Rio Lucero Indian Ditch Schematic



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Results The following summaries reflect the results of the water supply and power generation assessments completed for the Indian Ditch system for the Baseline Case.

Turbine Specifications – Baseline Case

Turbine	Head (ft)	Minimum Flow (cfs)	Average Flow (cfs)	Maximum Flow (cfs)
B	590	1	5	17
C	80	1	4	12
D	220	0	1	5
E	200	0	1	5

Turbine Capacity – Baseline Case

Turbine	Max kW	Min kW	Avg kW
B	579	45	178
C	57	4	20
D	59	0	10
E	58	0	18

Turbine Generation- Baseline Case

Turbine	Max kWh	Min kWh	Avg kWh
B	409,695	30,953	123,994
C	40,391	3,044	14,225
D	41,691	0	7,117
E	41,185	0	12,345

Conclusions – Baseline Case The two major contributing factors to the feasibility of hydropower generation are the head and flow. As shown in the above tables for the four turbines, Turbine B is the most feasible hydropower alternative for the Indian Ditch component of the Rio Lucero River. At 590 feet of head and an average flow of 5 cfs, the average monthly generation is 123,994 kWh for a total average annual generation of about 1,488 MWh. The capacity of Turbine B ranges from 45 kW to 579 kW due to the high variability of the power water available, ranging from 1 cfs to 17 cfs (pipeline capacity).

At 80 feet of head and an average flow of 4 cfs, the average monthly generation for Turbine C is 14,225 kWh for a total average annual generation of about 171 MWh. The capacity of Turbine C ranges from 4 kW to 57 kW due to the high variability of the water available, ranging from 1 cfs to 12 cfs (pipeline capacity). Turbine C is not as viable a hydropower alternative as Turbine B due to the low head of 80 feet, although the flow is similar to Turbine B. This is due to the fact that Turbine B has utilized 88 percent of the available head from the diversion dam (Point A) before the flow gets to Turbine C. Turbine C produces about 12 percent of the generation of Turbine B. Winter season stream flows are returned to the Rio Lucero from Turbine C in the Baseline Case.

At 220 feet of head and an average flow of 1 cfs, the average monthly generation for Turbine D is 7,117 kWh for a total average annual generation of about 85 MWh. The capacity of Turbine D ranges from 0 kW to 59 kW due to the variability of the water available, ranging from 0 cfs to 5 cfs (pipeline capacity). Turbine D is not as viable a hydropower alternative as Turbine B due to the low average flow of 1 cfs and no power generation from November to March each year, although the head is significant at 220 feet. This is due the fact that Turbine D does not utilize any of the excess natural flow. Turbine D produces about 6 percent of the generation of Turbine B.

At 200 feet of head and an average flow of 1 cfs, the average monthly generation for Turbine E is 12,345 kWh for a total average annual generation of about 148 MWh. The capacity of Turbine E ranges from 0 kW to 58 kW due to the variability of the water available, ranging from 0 cfs to 5 cfs (pipeline capacity). Turbine E is similar to Turbine C in overall generation and the head of 200 feet is appreciable. Turbine E utilizes the excess natural flows up to the pipeline capacity of 5 cfs during the irrigation season but generates no power from November to March each year. Turbine E produces about 10 percent of the generation of Turbine B. Winter generation, if at all possible, for Turbine E would greatly enhance the economic viability of this turbine. See the Maximum Case alternative following this section.

Sizing of Turbines B through E will be dependent on the monthly flow variability, flow duration curve, and the economic viability of the capital cost of construction for the capacity in kW versus generation in kWh. The smallest size of hydropower unit that the Federal Government will install is 2 MW and the smallest economically feasible hydropower unit installed to date by a private entity is 175 KW.

Maximum Case

Overview The same basic configuration of the project components is utilized in this option. However, under the settlement, there is potential to use most of the winter flows (November through March) for hydropower generation. A stream surplus could be declared during this period and the excess water utilized by the Tribe. For purposes of this alternative, it is assumed that 90% of the winter stream flow in the Rio Lucero is available for diversion and use by the Tribe. Due to difficulty with disposing of water from Turbine D, only Turbines B, C and E will be utilized during the winter period. Water from Turbine E can be returned directly to the Rio Lucero or used to help recharge the Buffalo Pasture.

Water supply estimates used for the power generation calculations were developed using the following criteria:

1. Study Period: 1935-1988 (Use USGS natural flow gage)
2. Irrigation Season: Use Rio Lucero Decree Allocation: 46.7%
3. Non-Irrigation Season: Use 90% of natural flows
4. Indian Ditch Irrigation Allocation: 56.0% of 46.7%
5. Winter Flows Use: All allocated flow goes to the Indian Ditch
6. Maximum Flows: Available flows capped at pipeline capacities for all months
7. Shortages: Irrigation shortages shared at all service areas.
8. Excess Flows: Routed to Turbine E because of higher head plus ease of disposal
9. Winter Flow Returns: Routed back to Rio Lucero or Buffalo Pasture

Table 2 in Appendix B summarizes the results of the water supply study. This tabulation documents the water delivered to each turbine for each month during the designated study period using the designated operating criteria. Two design concepts were utilized for the maximum case; a maximum flow design that utilizes the maximum flow for the turbine size in KW and an average flow design that utilizes the average flow for the turbine size in KW. The average flow design concept is approximately what the flow duration curve analysis would yield for turbine size if a small hydropower turbine company were to size the hydropower units.

Results The following summaries reflect the results of the water supply and power generation assessments completed for the Indian Ditch system for the Maximum Case.

Turbine Specifications – Maximum Case

Turbine	Head (ft)	Minimum Flow (cfs)	Average Flow (cfs)	Maximum Flow (cfs)
B	590	1	6	17
C	80	1	6	12
D	220	0	1	5
E	200	0	3	5

Turbine Capacity – Maximum Case – Maximum Flow Design

Turbine	Max kW	Min kW	Avg kW
B	579	45	223
C	57	4	26
D	59	0	10
E	58	5	41

Monthly Turbine Generation- Maximum Case – Maximum Flow Design

Turbine	Max kWh	Min kWh	Avg kWh
B	409,695	30,953	154,833
C	40,391	3,044	18,368
D	41,691	0	7,117
E	41,185	3,113	28,566

Monthly Turbine Generation- Maximum Case – Average Flow Design

Turbine	Avg kWh	Max kW
B	115,433	211
C	15,652	29
D	3,835	13
E	19,651	36

Conclusions – Maximum Case

As shown in the above tables for the four turbines, Turbine B is the most feasible hydropower alternative for the Indian Ditch component of the Rio Lucero River. At 590 feet of head and a maximum flow of 17 cfs, the average monthly generation is 154,833 kWh for a total average annual generation of about 1,858 MWh for the maximum flow design concept. For the maximum flow design concept, the capacity of Turbine B ranges from 45 kW to 579 kW due to the high variability of the power water available, ranging from 1 cfs to 17 cfs (pipeline capacity). For the average flow design concept, at 590 feet of head and an average flow of 6 cfs, the average monthly generation is 115,433 kWh for a total average annual generation of about 1,385

MWh. The capacity of Turbine B is set at 211 kW for the average flow design concept since the power water available is set at 6 cfs.

At 80 feet of head and a maximum flow of 12 cfs for the maximum flow design concept, the average monthly generation for Turbine C is 18,368 kWh for a total average annual generation of about 220 MWh. For the maximum flow design concept, the capacity of Turbine C ranges from 4 kW to 57 kW due to the high variability of the water available, ranging from 1 cfs to 12 cfs (pipeline capacity). For the average flow design concept, at 80 feet of head and an average flow of 6 cfs, the average monthly generation is 15,652 kWh for a total average annual generation of about 188 MWh. The capacity of Turbine C is set at 29 kW for the average flow design concept since the power water available is set at 6 cfs. Turbine C is not as viable a hydropower alternative as Turbine B due to the low head of 80 feet, although the flow is similar to Turbine B. This is due to the fact that Turbine B has utilized 88 percent of the available head from the diversion dam (Point A) before the flow gets to Turbine C. Turbine C produces about 12 percent of the generation of Turbine B. A total of 90% of the winter season streamflows are utilized from the Rio Lucero to Turbine C.

The average monthly generation and capacity for Turbine D is the same for the Maximum Case as the Baseline Case because winter flows are not utilized by Turbine D.

At 200 feet of head and a maximum flow of 5 cfs for the maximum flow design concept, the average monthly generation for Turbine E is 28,566 kWh for a total average annual generation of about 343 MWh. For the maximum flow design concept, the capacity of Turbine E ranges from 0 kW to 58 kW due to the variability of the water available, ranging from 0 cfs to 5 cfs (pipeline capacity). For the average flow design concept, at 200 feet of head and an average flow of 3 cfs, the average monthly generation is 19,651 kWh for a total average annual generation of about 236 MWh. The capacity of Turbine E is set at 36 kW for the average flow design concept since the power water available is set at 3 cfs. Turbine E is similar to Turbine C in overall generation and the head of 200 feet is appreciable. Turbine E produces about 18 percent of the generation of Turbine B. Winter generation at Turbine E in the Maximum Case increases the annual generation of this hydropower unit by 230 percent over the Baseline Case without winter generation.

Sizing of Turbines B through E will be dependent on the monthly flow variability, flow duration curve, and the economic viability of the capital cost of construction for the capacity in kW versus generation in kWh. The smallest size of hydropower unit that the Federal Government will install is 2 MW and the smallest economically feasible hydropower unit installed to date by a private entity is 175 KW.

Tenorio Ditch Project

Baseline Case

Overview The basic components of the Tenorio Ditch irrigation and hydroelectric project are presented in Figures 3 and 4. The available head for the project is about 300 feet but water supply is constrained by the decree allocation and the decision to divert winter flows only to the

Figure 3 Tenorio Ditch Hydropower Concept, Rio Lucero

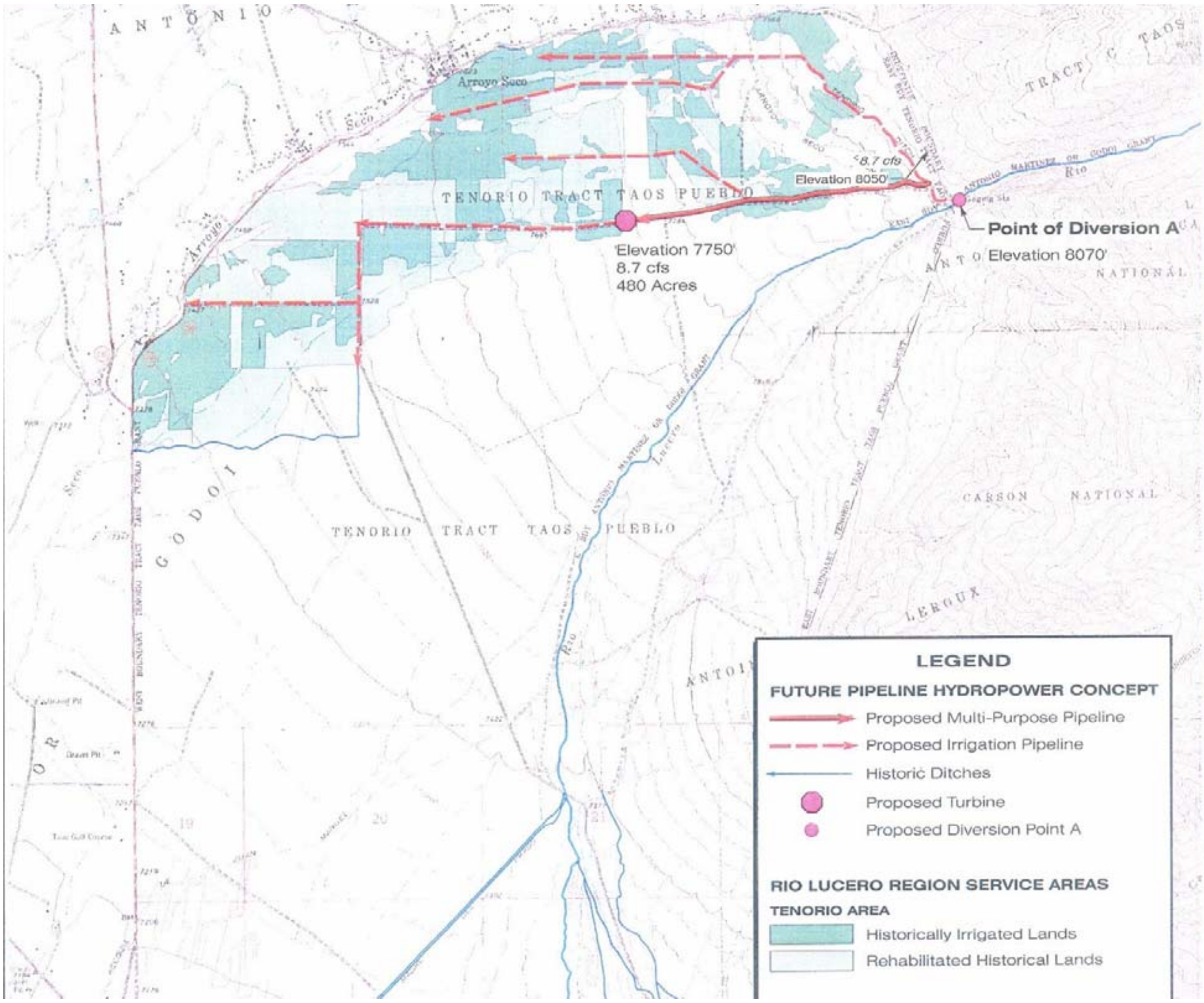
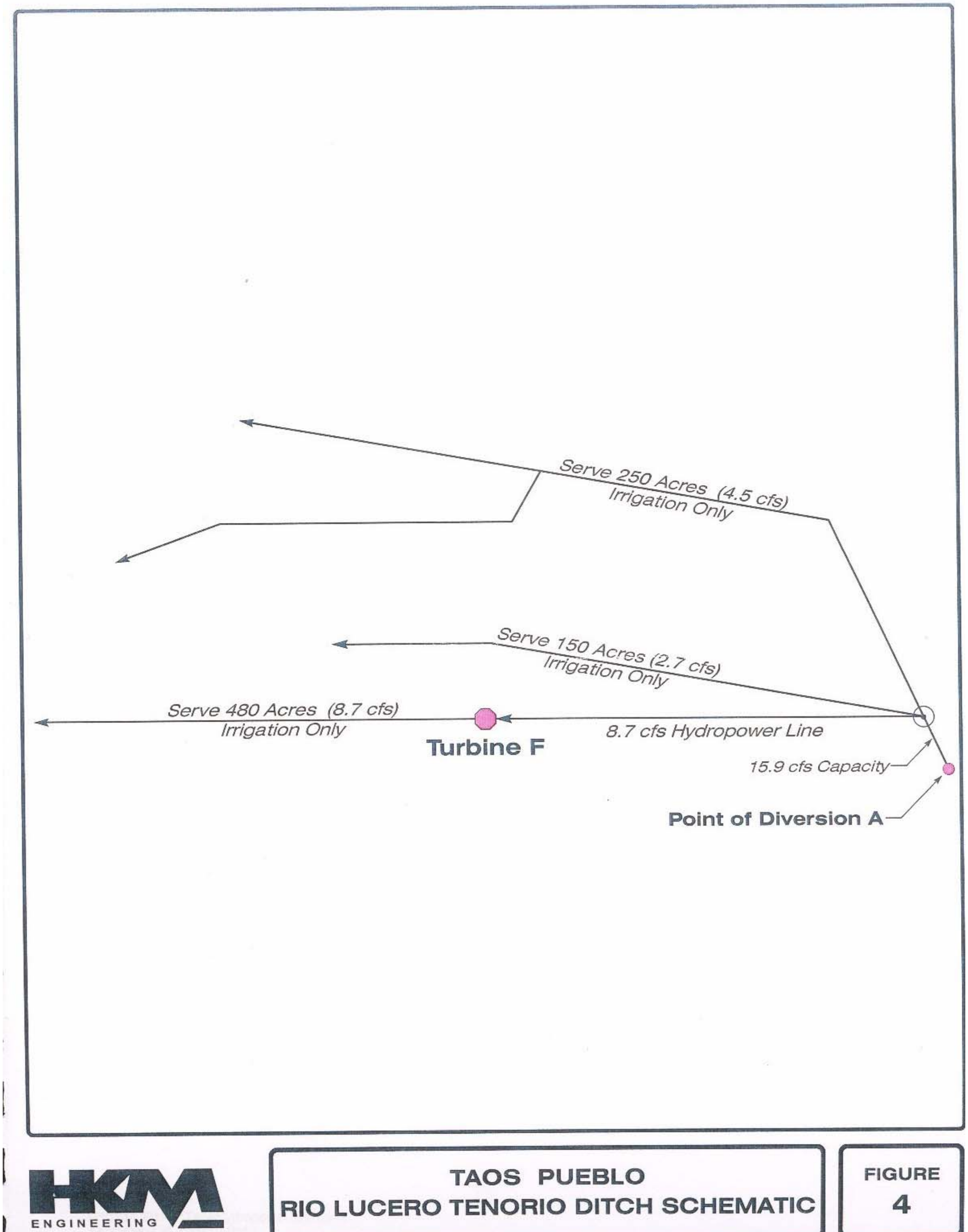


Figure 4 Rio Lucero Tenorio Ditch Schematic



Indian Ditch system. Further, multiple ditches deliver water to the service area which limits the capacity of flow carried by any one system. It is not logical to build penstocks for all the individual ditches. As such, only one multi-purpose irrigation/energy pipeline is recommended. This system is presented in Figure 3 and carries water for about 55 percent of the service area.

Water supply estimates used to estimate power generation potential were developed based on the following criteria.

1. Study Period: 1935 – 1988 (Use USGS natural flow gage)
2. Rio Lucero Decree Allocation: 46.7%
3. Tenorio Ditch Allocation: 44% of 46.7%
4. Diversion Capacity: 15.9 cfs (peak day (0.28 inches) for 880 acres @ 65% efficiency)
5. Winter Flows: None, all available flows allocated to Indian Ditch
6. Maximum Flows: Available monthly flows capped at the pipeline capacity of 8.7 cfs
7. Shortages: Irrigation shortages shared at all service areas

Table 7 in Appendix C summarizes the results of the water supply study. This tabulation documents the water delivered to Turbine F for each month during the 1935-1988 study period. As previously noted; power generation potential can be markedly increased as the Pueblo acquires water rights and increases their allocation percentage of the Rio Lucero.

Water available for power generation must be shared with two upstream ditch systems (250 acres and 150 acres) before the remaining water can be delivered to Turbine F. Shortages during the irrigation season are shared between the three primary ditch systems identified in Figure 4.

Power Generation The power generation for Turbine F is in Table 7, Appendix C for 1935-1988. The individual turbine flow is CFS was calculated from the power water supplied (acre-feet) to Turbine F, which was determined by the method described above. The head in feet for Turbine F was determined, the turbine efficiency utilized was 70 percent, and the power constant of 0.085 was utilized to obtain generation in kW. After the generation was determined, the operating time was calculated at 95 percent per month operational time in hours, and the kW generation multiplied by the operating hours resulted in total turbine generation in kWh for each month of the study.

Results The following summary documents the results of the water supply and power generation studies done for the Tenorio Ditch system.

Turbine Specifications – Baseline Case

Turbine	Head (ft)	Minimum Flow (cfs)	Average Flow (cfs)	Maximum Flow (cfs)
F	300	0	2	9

Turbine Capacity – Baseline Case – Maximum Flow Design

Turbine	Max kW	Min kW	Avg kW
F	155	0	39

Turbine Generation – Baseline Case – Maximum Flow Design

Turbine	Max kWh	Min kWh	Avg kWh
F	109,804	0	26,952

Monthly Turbine Generation- Baseline Case – Average Flow Design

Turbine	Avg kWh	Max kW
F	12,754	36

Conclusions – Baseline Case At 300 feet of head and a maximum flow of 9 cfs for the baseline case, the average monthly generation for Turbine F is 26,952 kWh for a total average annual generation of about 323 MWh. For the maximum flow design concept, the capacity of Turbine F ranges from 0 kW to 155 kW due to the high variability of the power water available, ranging from 0 cfs to 9 cfs. For the average flow design concept, at 300 feet of head and an average flow of 2 cfs, the average monthly generation is 12,754 kWh for a total average annual generation of about 153 MWh. The capacity of Turbine F is set at 36 kW for the average flow design concept since the power water available is set at 2 cfs. Turbine F on the Tenorio Ditch is not as viable a hydropower alternative as Turbine B on the Indian Ditch due to a lower head of 290 feet and that excess flows in the non-irrigation season are all diverted to Turbine B. Sizing of Turbine F by a hydropower company will be dependent on the monthly flow variability, flow duration curve, and the economic viability of the capital cost of construction for the capacity in kW versus generation in kWh. The smallest size of hydropower unit that the Federal Government will install is 2 MW and the smallest economically feasible hydropower unit installed to date by a private entity is 175 KW.

Maximum Case

Same as the Baseline Case since all the winter flows are being utilized by the Indian Ditch hydroelectric facilities.

Rio Pueblo Watershed

The "Taos Pueblo Irrigation Rehabilitation Plan for Rio Pueblo Region" identified one irrigation pipeline system to serve about 200 acres of new land in the southern part of the Grant Area. This pipeline could be modified to deliver water for both hydropower and irrigation purposes. However, it should be noted that the capability of this proposed multi-purpose pipeline to deliver supplemental water to selected historic ditches would be precluded by this option.

It is also proposed, in the settlement, to deliver 1000 acre-feet of winter and spring flow water from the Rio Pueblo de Taos to recharge the Buffalo Pasture. This pipeline could be used for both power generation and environmental purposes. This project will have senior priority over the future irrigation project.

During the settlement negotiations, the Pueblo was able to negotiate several major benefits relative to the use of the direct water resources of the Rio Pueblo de Taos. In summary, the Pueblo has the opportunity to continuously divert winter and early irrigation season water supplies up to proposed irrigation and hydropower capacities. During the July through September period, the standard stream allocation percentages would apply.

The two noted hydropower options are discussed in more detail in the following sections.

Future Irrigation Pipeline Projects

Baseline Case

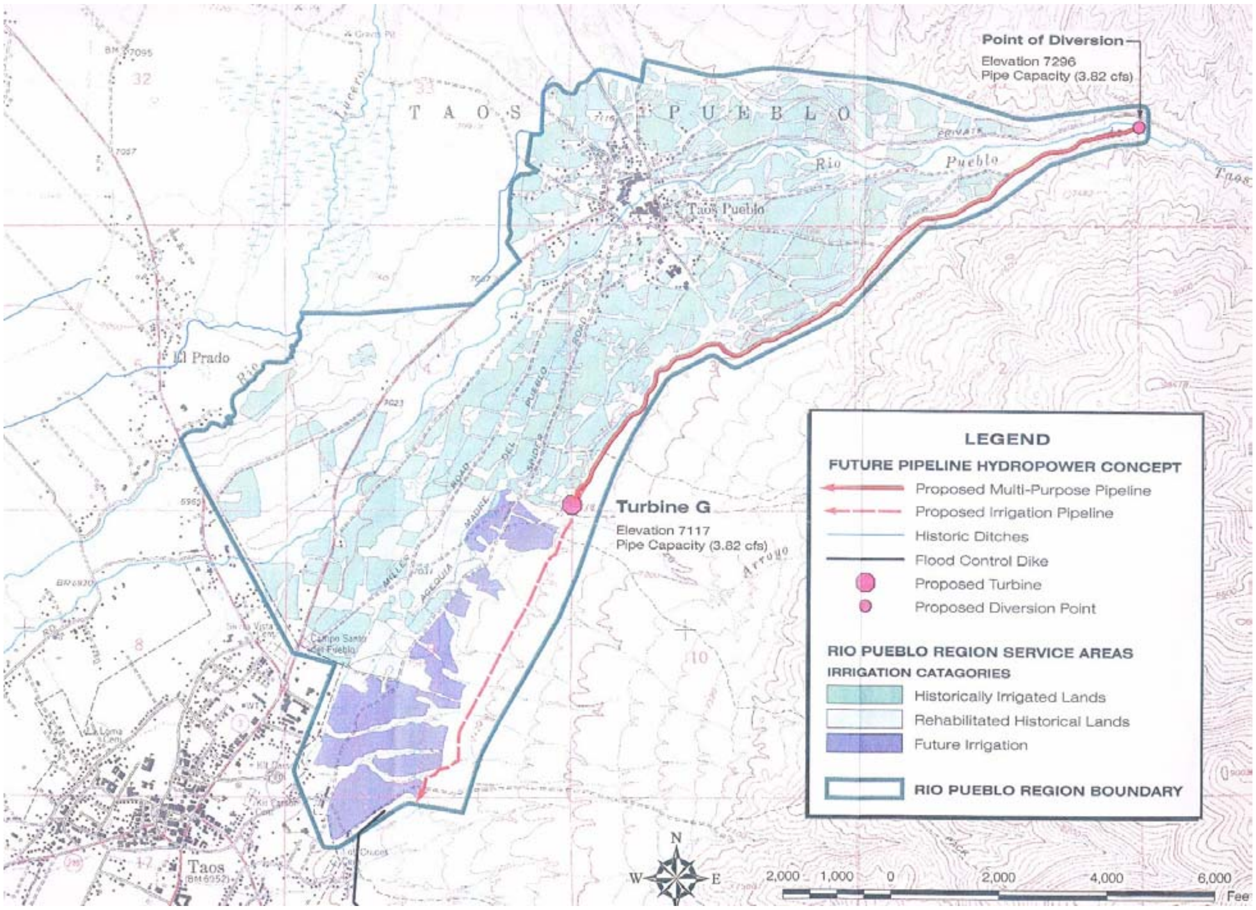
Overview Figure 5 presents the basic components of the proposed multi-purpose irrigation and hydropower projects. The elevation head difference is about 180 feet and the pipe capacity is set at 3.8 cfs to match the peak daily irrigation requirement for the future 200-acre project. Under this alternative, the Pueblo is restricted to the historical stream allocation percentage only during the July through September time period. Available direct flow supplies can be diverted up to the capacity of the hydropower facility after the Buffalo Project facility is supplied. Water would be returned to the Rio Pueblo via a large arroyo just downstream from Turbine G.

Water supply estimates used in this power generation analysis were developed using the following criteria.

1. Study Period: 1935-1988 (Use USGS natural flow gage)
2. July-September: Use Rio Pueblo de Taos Historic Allocation (64%)
3. Other Months: Use Available Flow After Buffalo Pasture Is Served
4. The Historic Irrigation Project (715 Acres) is the Senior User
5. Diversion Capacity: 3.82 cfs (peak day for 200 acres @ 62% efficiency)
6. Winter/ Spring Flows: Junior to the Buffalo Pasture but not restricted by the 64% historic allocation. Flows returned to Rio Pueblo de Taos via adjacent arroyo.

Table 8 of Appendix D identifies the water available for Turbine G and the amount of power generated by month.

Figure 5 Rio Pueblo Future Pipeline Hydropower Concept



Power Generation- Baseline Case Turbine G power generation (kWh) for 1935-1988 was calculated utilizing the available water supply. The individual turbine flow in CFS was calculated from the power water supplied (acre-feet) to Turbine G, which was determined by the method described above. The head in feet for Turbine G was determined to be 179 feet, the turbine efficiency utilized was 70 percent, and the power constant of 0.085 was utilized to obtain generation in kW. After the generation was determined, the operating time was calculated at 95 percent per month operational time in hours, and the kW generation multiplied by the operating hours resulted in total turbine generation in kWh for each month of the study.

Results – Baseline Case The following statistics summarize the results of the water supply and power generation assessment completed for the Rio Pueblo de Taos future pipeline system.

Turbine Specifications- Baseline Case

Turbine	Head (ft)	Minimum Flow (cfs)	Average Flow (cfs)	Maximum Flow (cfs)
G	179	0	3	4

Turbine Capacity – Baseline Case – Maximum Flow Design

Turbine	Max kW	Min kW	Avg kW
G	41	0	32

Turbine Generation – Baseline Case – Maximum Flow Design

Turbine	Max kWh	Min kWh	Avg kWh
G	28,778	0	22,380

Monthly Turbine Generation- Baseline Case – Average Flow Design

Turbine	Avg kWh	Max kW
G	18,161	32

Conclusions – Baseline Case At 179 feet of head and a maximum flow of 4 cfs for the maximum flow design concept, the average monthly generation for Turbine G is 22,380 kWh for a total average annual generation of about 269 MWh. For the maximum flow design concept, the capacity of Turbine G ranges from 0 kW to 41 kW due to the variability of the power water available, ranging from 0 cfs to 4 cfs. For the average flow design concept, at 179 feet of head and an average flow of 3 cfs, the average monthly generation is 18,161 kWh for a total average annual generation of about 218 MWh. The capacity of Turbine G is set at 32 kW for the average flow design concept since the power water available is set at 3 cfs. Sizing of Turbine G by a hydropower company will be dependent on the monthly flow variability, flow duration curve, and the economic viability of the capital cost of construction for the capacity in kW versus generation in kWh. The smallest size of hydropower unit that the Federal Government will install is 2 MW and the smallest economically feasible hydropower unit installed to date by a private entity is 175 KW.

Turbine G does not meet the minimum 2 MW size that Western Area Power Administration utilizes. If the hydropower unit is sized at average flow or about 3 cfs, then the turbine capacity would be 32 kW, considerably less then the smallest unit installed at 175 kW. The 179 feet of drop is sufficient but the average flow is low. Average flows would need to be increased to about 50 cfs or about seventeen times the current rate of 3 cfs to be feasible. The excess available flow above the 3.82 cfs pipeline capacity averages 669 acre-feet per month and peaks at 13,216 acre-feet per month. The average monthly flow could be increased from 3 cfs to 13 cfs by utilizing the excess flows and generation would subsequently increase by four and one-third times.

Maximum Case

Same as Baseline Case for Turbine G.

Buffalo Pasture Recharge Pipeline Project

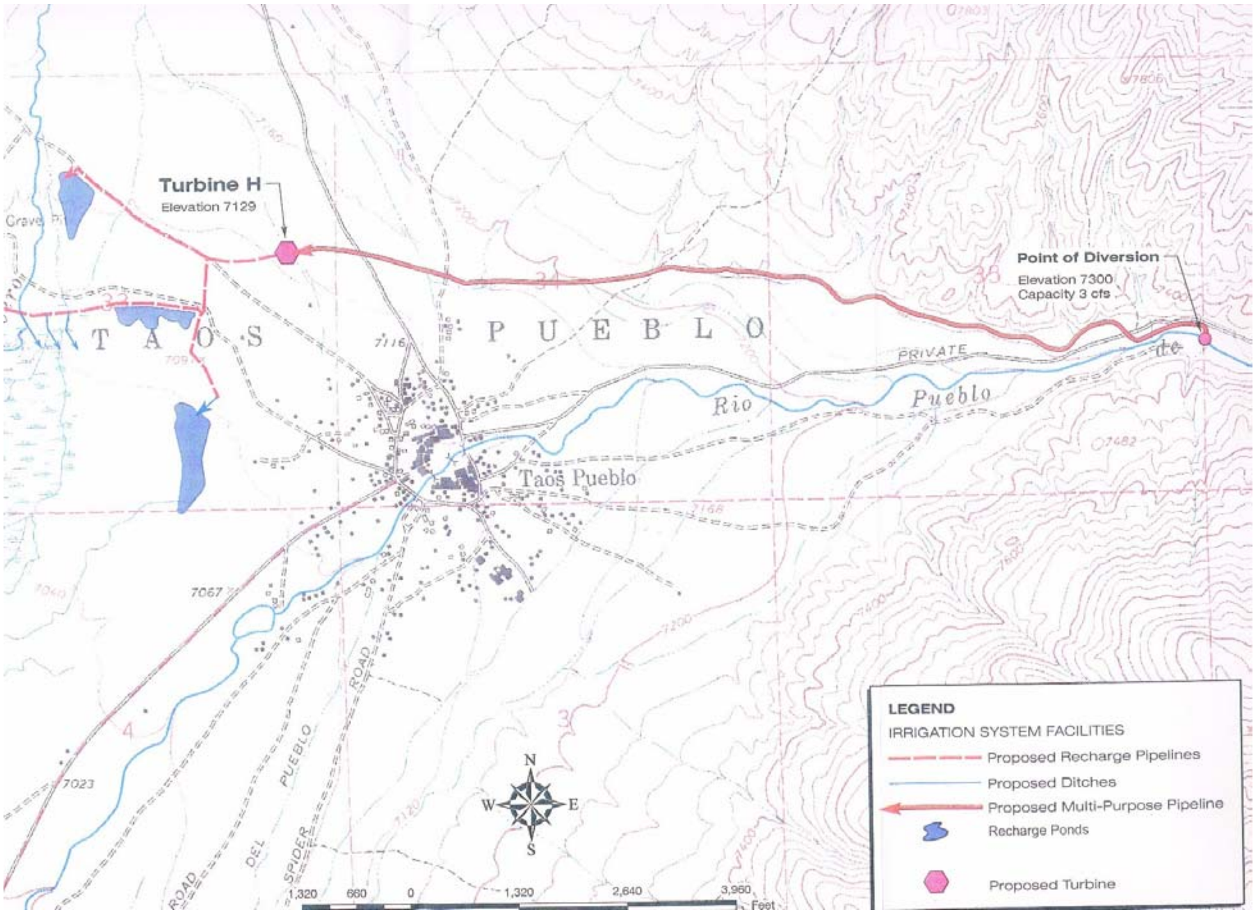
Overview A key component of the Tribe's water right settlement is to provide water to a recharge project for the sacred Buffalo Pasture area. Water availability studies were completed on both the Rio Lucero and Rio Pueblo de Taos drainages to evaluate whether water was available for recharge uses, above recently irrigated acreage irrigation demands. Figure 6 presents the basic components of the project and Table 9 of Appendix E shows the results of the water availability and power generation analyses.

Water supply estimates utilized in the power generation assessment were based on the following criteria:

1. Study Period: 1935 – 1988 (Use USGS natural flow gage)
2. Rio Pueblo de Taos Allocation: 64% (summer and winter)
3. Buffalo Pasture Project: Junior to historic irrigation and senior to future irrigation
4. Diversion Capacity: 3 cfs
5. Diversion Period: November – May, 160 acre-feet per month

Power Generation Buffalo Pasture power generation (kWh) for 1935-1988 was calculated utilizing the Buffalo Pasture recharge delivery (See Table 9 of Appendix E). The turbine flow in CFS was calculated from the power water supplied (acre-feet) to the turbine, which was determined by the method described above. The head in feet for Buffalo Pasture Turbine H was determined to be 171 feet, the turbine efficiency utilized was 70 percent, and the power constant of 0.085 was utilized to obtain generation in kW. After the generation was determined, the operating time was calculated at 95 percent per month operational time in hours, and the kW generation multiplied by the operating hours resulted in total turbine generation in kWh for each month of the study.

Figure 6 Buffalo Pasture Recharge Hydropower Project



Results The following statistics summarize the results of the water supply and power generation assessment completed for the Rio Pueblo de Taos Buffalo Pasture Recharge pipeline.

Turbine Specifications

Turbine	Head (ft)	Minimum Flow (cfs)	Average Flow (cfs)	Maximum Flow (cfs)
Buffalo Pasture H	171	0	2	3

Turbine Capacity – Baseline Case – Maximum Flow Design

Turbine	Max kW	Min kW	Avg kW
Buffalo Pasture H	29	0	16

Turbine Generation – Baseline Case – Maximum Flow Design

Turbine	Max kWh	Min kWh	Avg kWh
Buffalo Pasture H	18,718	0	10,881

Monthly Turbine Generation- Baseline Case – Average Flow Design

Turbine	Avg kWh	Max kW
Buffalo Pasture H	8,182	20

Conclusions At 171 feet of head and a maximum flow of 3 cfs for the maximum flow design concept, the average monthly generation for Buffalo Pasture Turbine H is 10,881 kWh for a total average annual generation of about 131 MWh. The capacity of the Buffalo Pasture Turbine ranges from 0 kW to 29 kW due to the low flow rate of the power water available, ranging from 0 cfs to 3 cfs. For the average flow design concept, at 171 feet of head and an average flow of 2 cfs, the average monthly generation is 8,182 kWh for a total average annual generation of about 98 MWh. The capacity of Turbine H is set at 20 kW for the average flow design concept since the power water available is set at 2 cfs. Sizing of the Turbine by a hydropower company will be dependent on the monthly flow variability, flow duration curve, and the economic viability of the capital cost of construction for the capacity in kW versus generation in kWh. The smallest size of hydropower unit that the Federal Government will install is 2 MW and the smallest economically feasible hydropower unit installed to date by a private entity is 175 KW.

The Buffalo Pasture Turbine does not meet the minimum 2 MW size that Western Area Power Administration utilizes. If the hydropower unit is sized at average flow or about 2 cfs, then the turbine capacity would be 16 kW, considerably less then the smallest unit installed at 175 kW. The 171 feet of drop is sufficient but the average flow is extremely low. Average flows would need to be increased to about 50 cfs or twenty-five times the current flow rate of 2 cfs to be feasible. The excess available flow above the 3 cfs pipeline capacity averages 669 acre-feet per month and peaks at 13,216 acre-feet per month. The average monthly flow could be increased from 2 cfs to 13 cfs by utilizing the excess flows and generation would subsequently increase by six and one-half times. The use of excess flows for either the Buffalo Pasture Turbine or the Rio Pueblo Turbine should be evaluated as an alternative.

Hydroelectric Turbine Selection

The type of turbine selected for the seven turbine sites for the Pueblo of Taos Hydropower Project is dependent on flow and net effective head (See Appendix F for General Hydropower Information). For irrigation canal/pipeline systems, the unit is sized based on the flow duration curve or approximately average flow and the type of turbine is selected based on turbine efficiency for the minimum flow.

In general, for high head (head greater then 200 feet), a twin nozzle Pelton turbine, rated at an efficiency at 92% for a flow range of 10%-100% of the maximum design flow for each nozzle, should be utilized. Pelton turbines for small hydropower units have been designed and installed for a head as low as 70 feet with a flow of 4.5 cfs according to Brett Bauer of Canyon Hydro Inc., Deming, Washington. For low head (head less then 200 feet), the Francis turbine rated at an efficiency of 89% should be utilized for a flow range of 40%-100% of the maximum design flow. For example, if the average flow is 100 cfs, then a Pelton turbine will only work if the minimum flow is 10 cfs or greater, and a Francis turbine will work if the minimum flow is 40 cfs or greater.

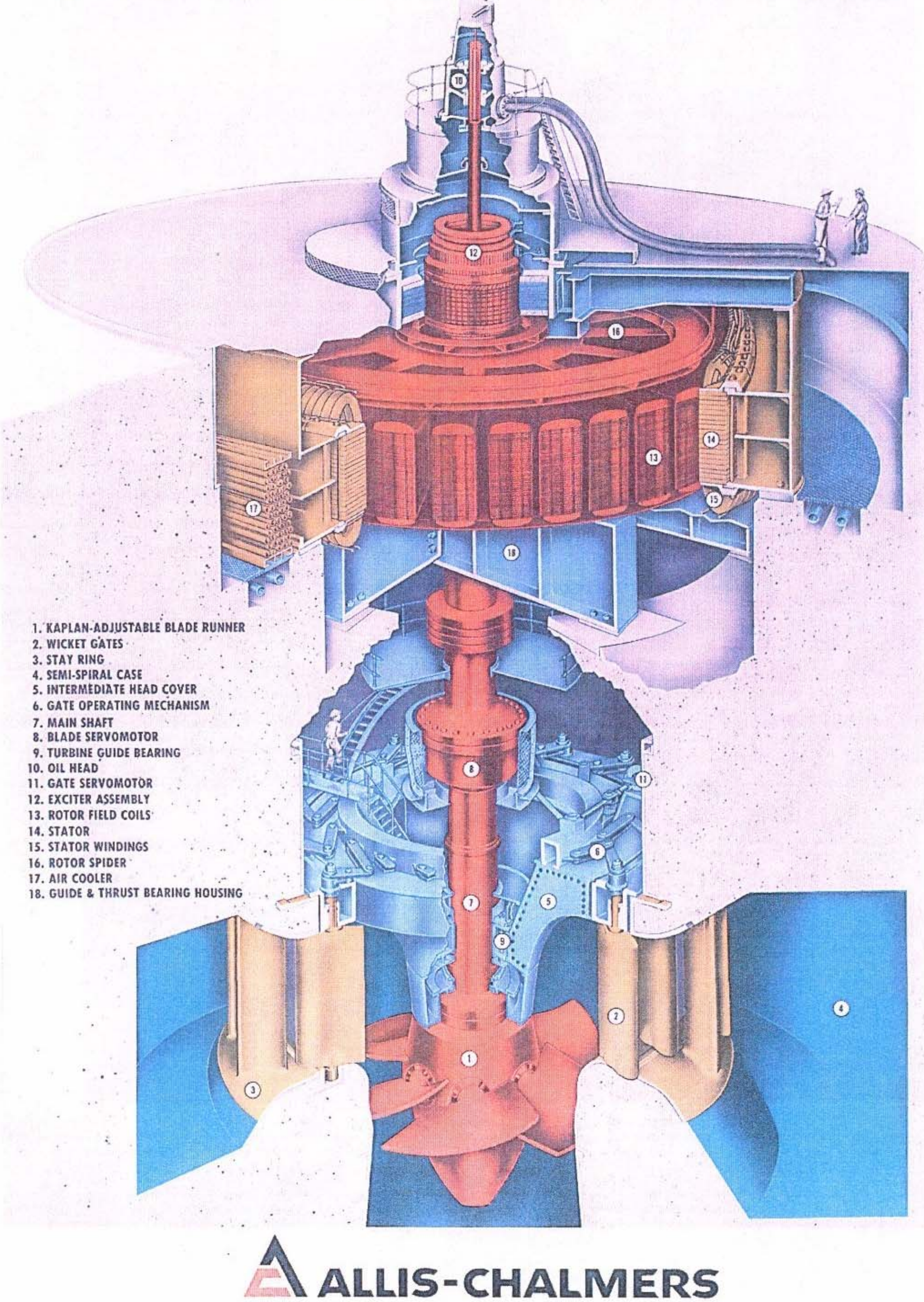
For the seven Taos Hydropower Units, Turbines B and C are the only two sites that meet the flow and head requirements of a Pelton turbine rated at an efficiency of 92% for a flow range of 10%-100% of the maximum design flow. Turbines D through H do not meet the flow requirements for a Pelton turbine with flows less then 3 cfs, but all turbines have a head greater then 70 feet. The minimum flow of 0 cfs for Turbines D through H is also a significant factor in turbine selection, since the turbines will not operate below 40% of design flow for Francis turbines. Turbines D through H have to be a Francis turbine and will not operate a significant amount of time due the 40% design flow minimum operating criteria.

Figure 7 deleted

A general cross-section diagram and parts list for a vertical Kaplan turbine (similar to Francis turbine) is shown in Figure 8. A photograph of a Pelton wheel from Walchensee, Germany is shown in Figure 9.

FIGURE
8

HYDRAULIC TURBINE GENERATOR UNIT



ALLIS-CHALMERS

FIGURE 9: PELTON WHEEL FROM WALCHENSEE, GERMANY HYDROPOWER STATION

Costs of Turbines and Related Hydroelectric Equipment

An appraisal level economic viability study was completed on all seven turbines. Construction costs, including the transformers, and switching gear were determined and evaluated against the net annual power revenue from generation. Francis turbines are expensive to install for small hydropower plants with a minimum cost of approximately $200,000 for each unit. Pelton turbines are more cost effective for small hydropower plants.

Appendix G contains data for the General Hydropower Cost Estimates and Economic Feasibility for Pueblo of Taos. The following Tables reflect the results of the Hydropower Cost Estimates and Economic Feasibility for the Pueblo of Taos.

As shown in Table 1, none of the turbines are economically viable. Table 1 shows the installed costs, annual costs, annual gross revenue, annual net loss or revenue, and unit costs for Turbines B through H for the average flow and maximum flow cases for hydropower study. The average flow case is generally the flow rate that small hydropower companies will utilize to size hydropower units. The maximum flow case was analyzed to determine the maximum hydropower unit capacity.

Total installed cost of the complete turbine/generator/penstock system would be $15,081,685 for the average flow case and $16,509,661 for the maximum flow case. Total annual cost of the complete turbine/generator/penstock system would be $1,357,490 for the average flow case and $1,486,020 for the maximum flow case. Annual net loss for the hydropower project would be $1,229,668 for the average flow case and $1,308,347 for the maximum flow case.

Unit costs range from $5,900 per KW for Turbine B for the maximum flow case to $88,000 per KW for Turbine D for the average flow case. Unit costs must range from $1,000 per KW to a maximum of $2,000 per KW to be economically feasible. Current power rates of $0.055 per KWHr would have to increase to a range of $0.216 per KWHr to $3.226 per KWHr for the Taos Hydropower Units to be economically feasible.

The average flow case and the maximum flow case do not significantly differ in economic value because the primary cost factor for the Taos Hydropower Units is the steel pipeline for penstocks, ranging in price from $72.00 per foot for 10-inch diameter pipe installed to $240.00 per foot for 30-inch diameter pipe installed. This compares to 100 psi PVC irrigation pipeline at $14.00 per foot for 10-inch diameter pipe installed to $100.00 per foot for 30-inch diameter pipe installed.

As shown in Table 2, the total incremental cost for the Taos Hydropower Units is $11,637,542 when compared to the irrigation only system, including all irrigation appurtenance costs. Even if all stand alone irrigation costs were credited to the hydropower project, a total of $11,637,542 of additional funds would have to have to be recovered by hydropower generation for the project to be economically feasible. However, the total annual net loss of $1,229,668 for hydropower generation does not allow for any hydropower capital recovery. The 13 pressure reduction valves are part of the irrigation appurtenance costs and total $325,000. The $325,000 in foregone irrigation costs due to the pressure reduction valves is only about 3 percent of the incremental cost increase for the hydropower units. Table 2 values are only shown for the average flow case because average flow represents design parameters that the turbines will be sized by small hydropower companies.

TABLE 2
COST ESTIMATES FOR THE PUEBLO OF TAOS HYDROPOWER PROJECT WITH IRRIGATION SYSTEM CREDITS – AVERAGE FLOW

ITEM	TOTAL HYDROPOWER INSTALLED COST WITH PIPELINE (DOLLARS)	TOTAL IRRIGATION SYSTEM CAPITAL COST (DOLLARS)	TOTAL INCREMENTAL COST OF HYDROPOWER SYSTEM VERSUS IRRIGATION SYSTEM (DOLLARS)	TOTAL ANNUAL NET (LOSS) OR REVENUE FOR HYDROPOWER (DOLLARS)
TURBINE B	$4,560,083	$1,213,908	$3,346,175	$(334,263)
TURBINE C	$ 639,714	$ 143,220	$ 496,494	$ (47,250)
TURBINE D	$1,814,314	$ 437,670	$1,376,644	$(160,773)
TURBINE E	$1,340,064	$ 270,100	$1,069,964	$(107,648)
TURBINE F	$3,105,891	$1,007,706	$2,098,185	$(271,141)
TURBINE G	$2,112,201	$ 153,326	$1,958,875	$(178,131)
TURBINE H	$1,509,419	$ 218,214	$1,291,205	$(130,461)
TOTAL	$15,081,685	$3,444,144	$11,637,542	$(1,229,668)

TAOS HYDROPOWER SYSTEM DESIGN AND COST ESTIMATES - AVERAGE FLOW CASE

ANNUAL PROJECT COST Item	O & M	Life (years)	Interest	Hydropower Field Cost	Unlisted Items 10%	Contingencies 20%	Engineering 20%	Total Installed Cost	O & M Cost	Capital Recovery Factor	Annual Cost of Capital	Total Annual Cost
TURBINE B with PIPE	1.50%	40	7.000%	$ 2,878,840	$ 287,884	$ 633,345	$ 760,014	$ 4,560,083	$ 68,401	0.07501	$ 342,048	$ 410,449
TURBINE C with PIPE	1.50%	40	7.000%	$ 403,860	$ 40,386	$ 88,849	$ 106,619	$ 639,714	$ 9,596	0.07501	$ 47,984	$ 57,580
TURBINE D with PIPE	1.50%	40	7.000%	$ 1,145,400	$ 114,540	$ 251,988	$ 302,386	$ 1,814,314	$ 27,215	0.07501	$ 136,090	$ 163,305
TURBINE E with PIPE	1.50%	40	7.000%	$ 846,000	$ 84,600	$ 186,120	$ 223,344	$ 1,340,064	$ 20,101	0.07501	$ 100,517	$ 120,618
TURBINE F with PIPE	1.50%	40	7.000%	$ 1,960,790	$ 196,079	$ 431,374	$ 517,649	$ 3,105,891	$ 46,588	0.07501	$ 232,970	$ 279,559
TURBINE G with PIPE	1.50%	40	7.000%	$ 1,333,460	$ 133,346	$ 293,361	$ 352,033	$ 2,112,201	$ 31,683	0.07501	$ 158,434	$ 190,117
TURBINE H with PIPE	1.50%	40	7.000%	$ 952,916	$ 95,292	$ 209,642	$ 251,570	$ 1,509,419	$ 22,641	0.07501	$ 113,220	$ 135,861
TOTAL				$ 9,521,266				$ 15,081,685	$ 226,225		$ 1,131,264	$ 1,357,490

HYDROPOWER SYSTEM DESIGN AND COST ESTIMATES - MAXIMUM FLOW CASE

ANNUAL PROJECT COST Item	O & M	Life (years)	Interest	Hydropower Field Cost	Unlisted Items 10%	Contingencies 20%	Engineering 20%	Total Installed Cost	O & M Cost	Capital Recovery Factor	Annual Cost of Capital	Total Annual Cost
TURBINE B with PIPE	1.50%	40	7.000%	$ 3,430,840	$ 343,084	$ 754,785	$ 905,742	$ 5,434,451	$ 81,517	0.07501	$ 407,633	$ 489,150
TURBINE C with PIPE	1.50%	40	7.000%	$ 445,860	$ 44,586	$ 98,089	$ 117,707	$ 706,242	$ 10,594	0.07501	$ 52,975	$ 63,568
TURBINE D with PIPE	1.50%	40	7.000%	$ 1,214,400	$ 121,440	$ 267,168	$ 320,602	$ 1,923,610	$ 28,854	0.07501	$ 144,288	$ 173,142
TURBINE E with PIPE	1.50%	40	7.000%	$ 879,000	$ 87,900	$ 193,380	$ 232,056	$ 1,392,336	$ 20,885	0.07501	$ 104,438	$ 125,323
TURBINE F with PIPE	1.50%	40	7.000%	$ 2,139,290	$ 213,929	$ 470,644	$ 564,773	$ 3,388,635	$ 50,830	0.07501	$ 254,179	$ 305,008
TURBINE G with PIPE	1.50%	40	7.000%	$ 1,346,960	$ 134,696	$ 296,331	$ 355,597	$ 2,133,585	$ 32,004	0.07501	$ 160,038	$ 192,042
TURBINE H with PIPE	1.50%	40	7.000%	$ 966,416	$ 96,642	$ 212,612	$ 255,134	$ 1,530,803	$ 22,962	0.07501	$ 114,824	$ 137,786
TOTAL				$ 10,422,766				$ 16,509,661	$ 247,645		$ 1,238,375	$ 1,486,020

TAOS HYDROPOWER SYSTEM DESIGN AND COST ESTIMATES - AVERAGE FLOW CASE

ANNUAL PROJECT COST Item	O & M	Life (years)	Interest	Hydropower Field Cost	Unlisted Items 10%	Contingencies 20%	Engineering 20%	Total Installed Cost	O & M Cost	Capital Recovery Factor	Annual Cost of Capital	Total Annual Cost
TURBINE B with PIPE	1.50%	40	7.000%	$ 2,878,840	$ 287,884	$ 633,345	$ 760,014	$ 4,560,083	$ 68,401	0.07501	$ 342,048	$ 410,449
TURBINE C with PIPE	1.50%	40	7.000%	$ 403,860	$ 40,386	$ 88,849	$ 106,619	$ 639,714	$ 9,596	0.07501	$ 47,984	$ 57,580
TURBINE D with PIPE	1.50%	40	7.000%	$ 1,145,400	$ 114,540	$ 251,988	$ 302,386	$ 1,814,314	$ 27,215	0.07501	$ 136,090	$ 163,305
TURBINE E with PIPE	1.50%	40	7.000%	$ 846,000	$ 84,600	$ 186,120	$ 223,344	$ 1,340,064	$ 20,101	0.07501	$ 100,517	$ 120,618
TURBINE F with PIPE	1.50%	40	7.000%	$ 1,960,790	$ 196,079	$ 431,374	$ 517,649	$ 3,105,891	$ 46,588	0.07501	$ 232,970	$ 279,559
TURBINE G with PIPE	1.50%	40	7.000%	$ 1,333,460	$ 133,346	$ 293,361	$ 352,033	$ 2,112,201	$ 31,683	0.07501	$ 158,434	$ 190,117
TURBINE H with PIPE	1.50%	40	7.000%	$ 952,916	$ 95,292	$ 209,642	$ 251,570	$ 1,509,419	$ 22,641	0.07501	$ 113,220	$ 135,861
TOTAL				$ 9,521,266				$ 15,081,685	$ 226,225		$ 1,131,264	$ 1,357,490

HYDROPOWER SYSTEM DESIGN AND COST ESTIMATES - MAXIMUM FLOW CASE

ANNUAL PROJECT COST Item	O & M	Life (years)	Interest	Hydropower Field Cost	Unlisted Items 10%	Contingencies 20%	Engineering 20%	Total Installed Cost	O & M Cost	Capital Recovery Factor	Annual Cost of Capital	Total Annual Cost
TURBINE B with PIPE	1.50%	40	7.000%	$ 3,430,840	$ 343,084	$ 754,785	$ 905,742	$ 5,434,451	$ 81,517	0.07501	$ 407,633	$ 489,150
TURBINE C with PIPE	1.50%	40	7.000%	$ 445,860	$ 44,586	$ 98,089	$ 117,707	$ 706,242	$ 10,594	0.07501	$ 52,975	$ 63,568
TURBINE D with PIPE	1.50%	40	7.000%	$ 1,214,400	$ 121,440	$ 267,168	$ 320,602	$ 1,923,610	$ 28,854	0.07501	$ 144,288	$ 173,142
TURBINE E with PIPE	1.50%	40	7.000%	$ 879,000	$ 87,900	$ 193,380	$ 232,056	$ 1,392,336	$ 20,885	0.07501	$ 104,438	$ 125,323
TURBINE F with PIPE	1.50%	40	7.000%	$ 2,139,290	$ 213,929	$ 470,644	$ 564,773	$ 3,388,635	$ 50,830	0.07501	$ 254,179	$ 305,008
TURBINE G with PIPE	1.50%	40	7.000%	$ 1,346,960	$ 134,696	$ 296,331	$ 355,597	$ 2,133,585	$ 32,004	0.07501	$ 160,038	$ 192,042
TURBINE H with PIPE	1.50%	40	7.000%	$ 966,416	$ 96,642	$ 212,612	$ 255,134	$ 1,530,803	$ 22,962	0.07501	$ 114,824	$ 137,786
TOTAL				$ 10,422,766				$ 16,509,661	$ 247,645		$ 1,238,375	$ 1,486,020

TAOS HYDROPOWER STUDY
TOTAL COSTS FOR INSTALLED HYDROPOWER UNITS VERSUS IRRIGATION SYSTEM
MAXIMUM CASE - TURBINE SIZE BASED ON AVERAGE FLOW - NOVEMBER 2006

TURBINE UNIT	HYDROPOWER UNIT CAPITAL COST ($)	PIPE DIAMETER (INCHES)	PIPE LENGTH (FEET)	STANDARD STEEL PIPE INSTALLED ($/FOOT)	TOTAL INSTALLED COST FOR STEEL PIPE ($)	TOTAL INSTALLED COST FOR HYDROPOWER SYSTEM WITH PIPE ($)	TOTAL IRRIGATION SYSTEM APPURTENANCE COSTS ($)	100 PSI PVC - PIP PIPE INSTALLED ($/FOOT)	TOTAL INSTALLED COST FOR PVC PIPE ($)	TOTAL IRRIGATION SYSTEM INSTALLED COSTS ($)	TOTAL INCREMENTAL INSTALLED COST OF HYDROPOWER SYSTEM ($)
B	$316,500.00	24	13486	$190	$2,562,340	$4,560,083	$162,000	$78	$1,051,908	$1,213,908	$3,346,175
C	$43,500.00	20	2310	$156	$360,360	$639,714	$45,800				
		21	2310					$62	$143,220	$143,220	$496,494
D	$19,500.00	14	11259	$100	$1,125,900	$1,814,314					
		15	11259				$99,900	$30	$337,770	$437,670	$1,376,644
E	$54,000.00	14	7920	$100	$792,000	$1,340,064					
		15	7920				$32,500	$30	$237,600	$270,100	$1,069,964
F		18	12724	$134	$1,705,016			$44	$559,856		
F		20	114	$156	$17,784						
F		21	114					$62	$7,068		
F		24	69	$190	$13,110			$78	$5,382		
F		30	712	$240	$170,880			$100	$71,200		
F-TOTAL	$54,000.00				$1,906,790	$3,105,891	$364,200		$643,506	$1,007,706	$2,098,185
G		12	3954	$90	$355,860			$19	$75,126		
G		14	9296	$100	$929,600						
G		15	9296					$30	$278,880		
G-TOTAL	$48,000.00				$1,285,460	$2,112,201	$78,200		$354,006	$432,206	$1,679,995
H		10	8093	$72	$582,696			$14	$113,302		
H		12	548	$90	$49,320			$19	$10,412		
H		14	2909	$100	$290,900						
H		15	2909					$30	$87,270		
H-TOTAL	$30,000.00				$922,916	$1,509,419	$94,500		$210,984	$305,484	$1,203,935
TOTAL						$15,081,685				$3,810,294	$11,271,391

TAOS HYDROPOWER STUDY
TOTAL COSTS FOR INSTALLED HYDROPOWER UNITS VERSUS IRRIGATION SYSTEM
MAXIMUM CASE - TURBINE SIZE BASED ON AVERAGE FLOW - NOVEMBER 2006

TURBINE UNIT	HYDROPOWER UNIT CAPITAL COST ($)	PIPE DIAMETER (INCHES)	PIPE LENGTH (FEET)	STANDARD STEEL PIPE INSTALLED ($/FOOT)	TOTAL INSTALLED COST FOR STEEL PIPE ($)	TOTAL INSTALLED COST FOR HYDROPOWER SYSTEM WITH PIPE ($)	TOTAL IRRIGATION SYSTEM APPURTENANCE COSTS ($)	100 PSI PVC - PIP PIPE INSTALLED ($/FOOT)	TOTAL INSTALLED COST FOR PVC PIPE ($)	TOTAL IRRIGATION SYSTEM INSTALLED COSTS ($)	TOTAL INCREMENTAL INSTALLED COST OF HYDROPOWER SYSTEM ($)
B	$316,500.00	24	13486	$190	$2,562,340	$4,560,083	$162,000	$78	$1,051,908	$1,213,908	$3,346,175
C	$43,500.00	20	2310	$156	$360,360	$639,714	$45,800				
		21	2310					$62	$143,220	$143,220	$496,494
D	$19,500.00	14	11259	$100	$1,125,900	$1,814,314					
		15	11259				$99,900	$30	$337,770	$437,670	$1,376,644
E	$54,000.00	14	7920	$100	$792,000	$1,340,064					
		15	7920				$32,500	$30	$237,600	$270,100	$1,069,964
F		18	12724	$134	$1,705,016			$44	$559,856		
F		20	114	$156	$17,784						
F		21	114					$62	$7,068		
F		24	69	$190	$13,110			$78	$5,382		
F		30	712	$240	$170,880			$100	$71,200		
F-TOTAL	$54,000.00				$1,906,790	$3,105,891	$364,200		$643,506	$1,007,706	$2,098,185
G		12	3954	$90	$355,860			$19	$75,126		
G		14	9296	$100	$929,600						
G		15	9296					$30	$278,880		
G-TOTAL	$48,000.00				$1,285,460	$2,112,201	$78,200		$354,006	$432,206	$1,679,995
H		10	8093	$72	$582,696			$14	$113,302		
H		12	548	$90	$49,320			$19	$10,412		
H		14	2909	$100	$290,900						
H		15	2909					$30	$87,270		
H-TOTAL	$30,000.00				$922,916	$1,509,419	$94,500		$210,984	$305,484	$1,203,935
TOTAL						$15,081,685				$3,810,294	$11,271,391

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Study Conclusions and Recommendations

The Pueblo of Taos Hydropower System does not have the capital recovery to design and install hydropower units for any of the proposed turbine sites in place of the irrigation pipelines. All of the turbines have sufficient head, but the flow is not sufficient to generate electricity at a rate that will allow for a reasonable capital recovery. The total incremental cost for the Taos Hydropower Units is $11,637,542 when compared to the irrigation only system, including all irrigation appurtenance costs. In comparison, the foregone costs for irrigation total only $325,000 for the 13 pressure reduction valves. Potential turbine sites that bifurcate off of the main irrigation system to a forebay reservoir, intake structure, and steel penstock, with head of 100 feet or greater and length less then 2000 feet, should be further investigated

See Appendices for additional data sheets from the HKM Study

End of HKM Study

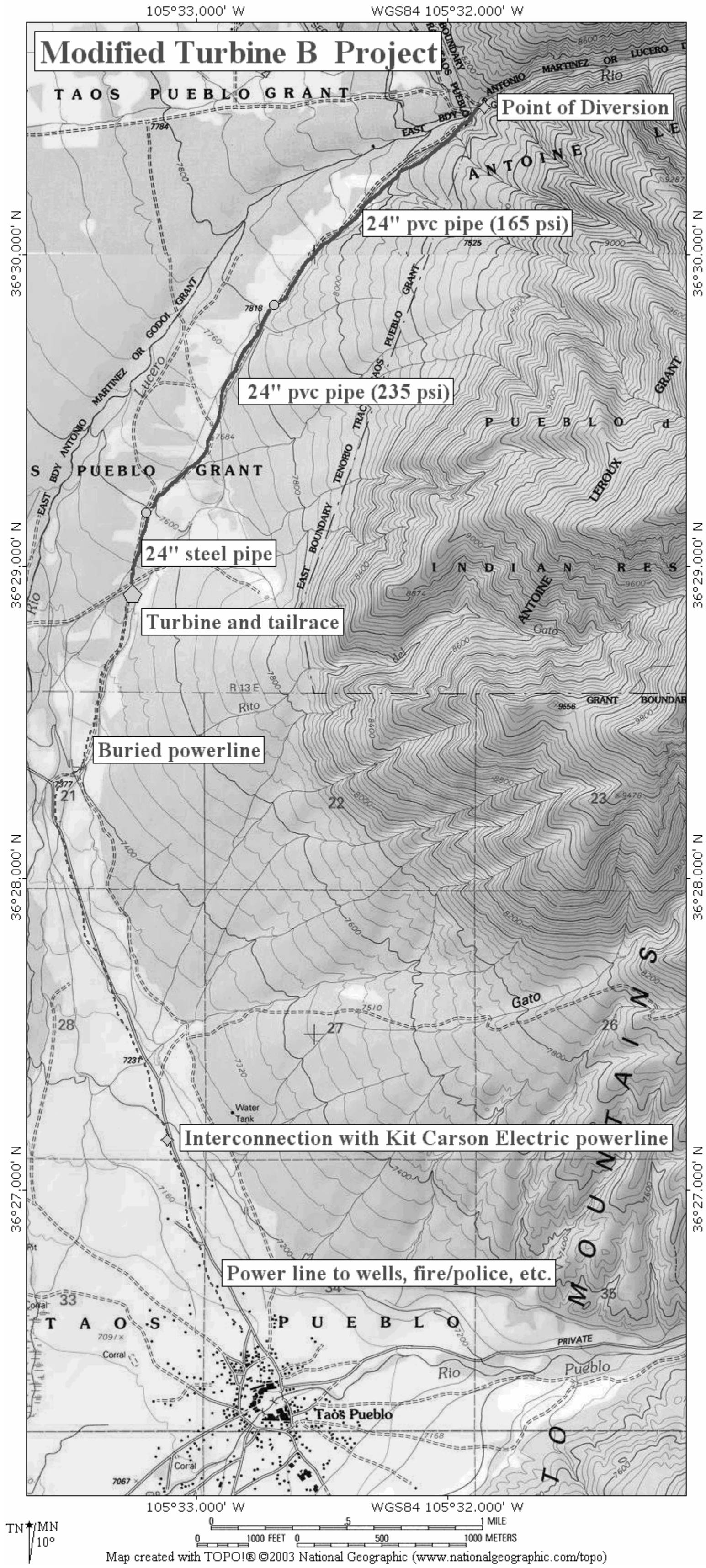
REVISED ASSESSMENT OF THE IRRIGATION HYDROELECTRIC OPTION

There are several assumptions in the HKM Engineering study that are leading to a high cost projection per kWhr for hydroelectric projects. These assumptions need to be examined. In consultations with Canyon Hydro of Deming, Washington, the option was suggested of using high-grade PVC pipe where steel pipe was not absolutely required, in order to lower penstock costs. Also, the engineering costs of $760,014 for the Turbine B option used by HKM are overstated, as vendors such as Canyon Hydro have stated they supply much of this engineering work as part of an equipment purchase. The engineering of the penstock should be considered part of the irrigation rehabilitation plan and not a cost to be burdened on the hydroelectric option. HKM also includes a "Contingencies" cost for the Turbine B option of $633,345. This amount appears to be very high as it is equivalent to the total cost of a turbine and controls as quoted by Canyon Hydro. Therefore, an alternative or revised estimate of the incremental cost of installing a hydroelectric system during the rehabilitation of the Indian Ditch has been developed below.

The HKM Engineering Study uses costs for steel pipe in areas where lower pipe pressures in the majority of the penstock would allow for use of High Density Polypropylene (HDPE) or water main grade PVC pipe. The C905 grade water main pipe comes with a gasket connection that also lowers installation cost (no welding). The HKM study uses a cost of $190. per foot of installed steel pipe. The use of the HDPE or PVC pipe, which are similar in price, results in a cost of 103. /ft for the penstocks. This lowers the cost of the Turbine B penstock by $87./ft. for 12,166 ft. totaling $1,058,442 in savings. Projects that have used HDPE include a 4.5 MW project in Black Bear Alaska that has a static head of 1,490 ft. and the 271 kW Goat Lake Project in Skagway, Alaska with 170 ft. static head. The Low Impact Hydro Institute website lists others.

By installing the maximum flow turbine with a capacity of 579 kW, rather than the average flow turbine rated at 212 kW, the increase of 472,968 kWhr/yr. will generate at a minimum, an additional $1.2 million, in revenues over the 40 yr. life of the turbines. The additional 367 kW capacity will only add about $220,000. in turbine costs (cost estimates from Canyon Hydro). The "Modified Turbine B Project" utilizes from the point of diversion 6,743 ft. of 24 " C905-DR 25 pipe with a pressure rating of 165 psi, followed by 5,403 ft. of 24" C905-DR 18" rated 235 psi, and then 1320 ft. of 24" steel pipe where static head exceeds 235 psi.

TOPO! map printed on 12/14/06 from "Untitled.tpo"



Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

The project cost would then comprise the following:

6,743 ft. of 24 " C905-DR 25 pipe, installed @ $90. /ft.	$606,870.	
5,403 ft. of 24" C905-DR 18 pipe, installed @ $106. /ft.	572,718.	
1,320 ft. of 24" steel pipe, installed @ $ 180. ft.	237,600.	
	1,417,188.	
Total penstock		1,417,188.
Turbine, controls and civil works, engineering @ $1,200. /kW x 579 kW		868,500.
Project management		150,000.
		2,243,688.

Offset of cost of irrigation pipe and pressure reduction valves (as estimated by HKM)	-1,213,908.

. The additional 367 kW capacity will only add about $220,000. in turbine costs (cost estimates from Canyon Hydro).

Incremental cost of hydroelectric	1,221,780.
2.9-mile power line	160,000.
Mini-grid and utility interconnection	89,500.
Total cost of project	1,471,280.

Incremental "mini-grid " cost		$89,500.
4,000 ft buried line	$38,000.	
9 utility interconnection panels	$41,500	
Engineering	10,000	

ELECTRIC LOAD IN TAOS PUEBLO VILLAGE AREA SERVICED BY "MINI-GRID" INCLUDING ADDITIONAL CAPACITY FOR MEAT STORAGE FACILITY

North	Annual Kwh
T.P. Utility Wells	44,486
Law Enforcement	21,588
Seniors	14,522
Environment	11,458
Tribal Government	24,883
	116,937
South	
Community Center	10,826
Day School/Headstart	146,933
Health and Human Services	23,315
	181,074
Total Annual kWh	298,011
Meat/food Storage Facility (3,000 sq. ft. and 48-hp. loads)	105,000

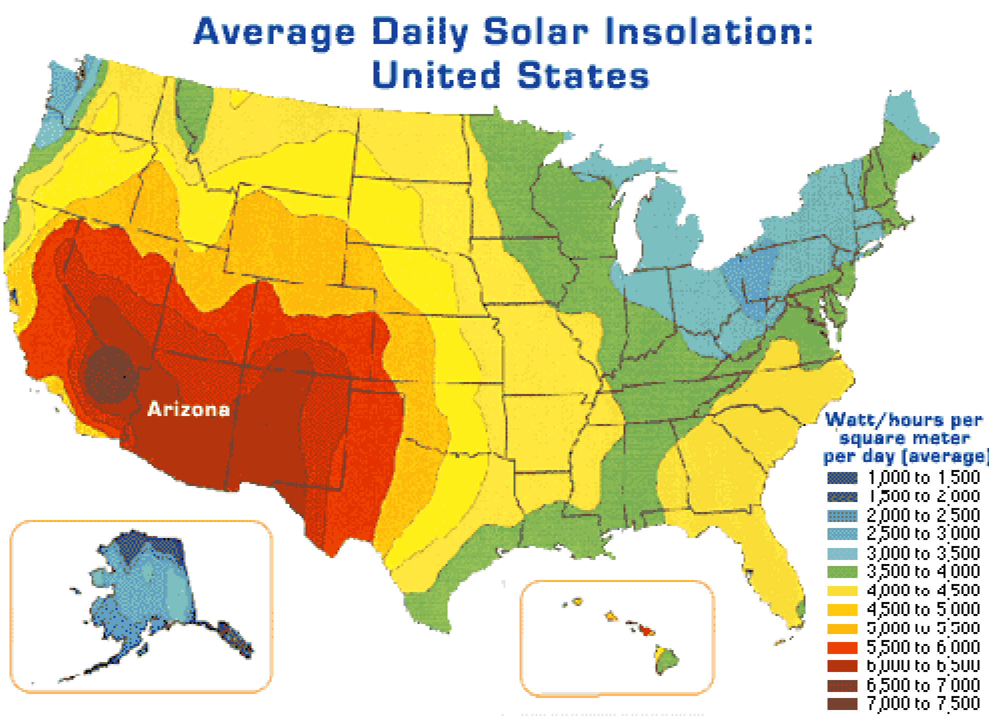
Total Annual Demand	403,011 kWh	
Avoided cost @ $0.069/kWh		$27,807. /yr.
Total Generation of 579 kW turbine	1,857,996 kWh	
Available for export to Kit Carson Electric	1,454,985 kWh	
Sale price @ $.065/kWh (present Tri-state wholesale price of $0.055/kWh + one cent/kWh for Renewable Energy Credit)		$94,574. /yr.
Total Revenue/Avoided Cost		$122,381. /yr.

See the Draft of Business Plan in section VI. The business plan is based on the modified assessment of Turbine B. It should be reemphasized that the HKM estimates all use steel pipe for the entire length of the penstocks when HDPE is an excellent pipe with elasticity to handle surges and pressures.

SOLAR

A. BASELINE RESOURCE ASSESSMENT

Taos Pueblo is located in an area of the U.S. with extremely high solar insolation values. According to the map below, the solar insolation is between 6,000 to 7,000 watts per sq. meter per day. Although the traditional lands are tucked up against the mountains with some morning shading and additional cloud cover, Tract A to the west receives the first rays of morning, and is often open to the sun when clouds are piled up against the mountains.



Map courtesy of NREL.

In the map above, Taos is located in the 6,500 to 7,000 watt/hrs per sq. meter zone. Taos is renown for its sunny days and "see for miles" visibility, even throughout the winter. The 7,000 ft. altitude results in an increased intensity of insolation due to the shorter pathlength through the atmosphere. Taos is renown for the number of solar homes, as well as having the world's most powerful solar-powered radio broadcasting station. Photovoltaic systems are in wide use, and Kit Carson Electric Cooperative is planning a large solar array.

Collector Orientation	Flat Plate Tilted South at Latitude	**Collector Orientation**	Flat Plate Tilted South at Latitude -1
Cell I.D.	202370	**Cell I.D.**	202370
Longitude	-105.649	**Longitude**	-105.649
Latitude	36.471	**Latitude**	36.471
Units	kWhr/m2/day	**Units**	kWhr/m2/day

January	5.11	**January**	4.38
February	5.62	**February**	5.05
March	6.15	**March**	5.87
April	6.39	**April**	6.49
May	6.40	**May**	6.84
June	6.43	**June**	7.04
July	6.18	**July**	6.68
August	5.99	**August**	6.21
September	6.06	**September**	5.95
October	6.15	**October**	5.66
November	5.28	**November**	4.60
December	4.94	**December**	4.17
Annual	5.89	**Annual**	5.74

Collector Orientation	Horizontal Flat Plate	**Collector Orientation**	Vertical Flat Plate Facing South
Cell I.D.	202370	**Cell I.D.**	202370
Longitude	-105.649	**Longitude**	-105.649
Latitude	36.471	**Latitude**	36.471
Units	kWhr/m2/day	**Units**	kWhr/m2/day
January	2.98	**January**	5.21
February	3.84	**February**	5.08
March	5.00	**March**	4.48
April	6.17	**April**	3.48
May	6.97	**May**	2.69
June	7.34	**June**	2.36
July	6.80	**July**	2.44
August	5.97	**August**	2.93
September	5.35	**September**	3.82
October	4.47	**October**	4.96
November	3.24	**November**	5.06
December	2.73	**December**	5.14
Annual	5.07	**Annual**	3.97

TECHNICAL RESOURCES

Photovoltaic panels or p.v. panels are the most widely used solar technology for producing electricity and can be used for water pumping, residential, or larger scale applications such as

roof top arrays on buildings. (see example from Geneva, Switzerland below) There are three companies in Taos that specialize in photovoltaic installations, so this technology is readily available. Several tribal members have p.v. panels powering their homes.
There is a 8 MW photovoltaic array scheduled to be built for Xcel Energy in the San Luis Valley north of Taos Pueblo. Kit Carson Electric Cooperative, the utility that distributes power in Taos Pueblo, has also become involved in photovoltaics by securing Clean Energy Bonds for financing a p.v. production plant to be built by Spire Corporation in Questa N.M. just 30 miles north of Taos Pueblo. This facility will have the long-term benefit of lowering the cost of p.v. panels in the Taos area.

The 640 watt array below is at the Red Willow Center and is pumping water from a shallow well supplying irrigation to three greenhouses and one acre of fields.

An array of this size could supply power to residences at Taos Pueblo that are located without easy access to the grid. Combined with a propane refrigerator, this array can supply basic lighting and power needs. The panels do not need to be on a tracker to be effective for residential use on a year round basis. The array at Red Willow Center is on a tracker to optimize the amount of water that can be pumped during the growing season.

The 35 kW array above would be more than adequate for supplying power to the Taos Pueblo Utilities north side municipal wells. A similar sized array would also power the two municipal well pumps on the Southside on Spider Rock Rd. The arrays could be shielded from sight by fencing as demonstrated by the photo of the solar array at the Red Willow Center. Another strategy is to excavate down and use the excavated earth to create a berm. A low hedge of chamisa could then be planted on the berm to create a natural, pleasing screen to remove the solar array from sight.

The artist rendering below is of 25 kW stirling engine gensets that could be deployed in Tract A. This technology is being used to supply power to southern California utilities as part of a 1000 MW power purchase agreement. About 9 acres are required per MW (megawatt) capacity of Stirling gensets. The cost of this technology is presently economical only in a high-cost power

market like California, however within three or four years the Stirling gensets are projected to be in mass production. (phone conversation with Stirling representative, Steve Trimble,2006)

The concentrated solar power technology shown above is being developed by IAUS based in Utah which has signed a $1,500,000. contract to build a 1 MW array in Nevada. This system utilizes fresnel lenses to superheat and pressurize water to 1,800 degress F. that is then flashed into steam to operate a highly efficient turbine. This system has roughly the same efficiency as Stirling, however it is projected to be less expensive ($.05/kW and can handle winds up to 90 mph vs. 50 mph for the Stirling gensets. This latter advantage is important in regards to Tract A where winds can gust over 50 mph during periods of high winds.

According to the Department of Energy, at least 7,000 MW of centralized renewable power plants will be built by the year 2020, and possibly much more. The U.S. Department of Energy's goal is to install 1,000 megawatts (MW) of new concentrating solar power systems in the southwestern United States by 2010. At this level of deployment, and with further reductions in component costs, solar power electricity costs could lower to $0.07/kilowatt-hour.

Solar Electric Supply to Utilities: Taos Pueblo as Large-Scale Power Supplier

There is a long term opportunity for Taos Pueblo to supply power generated in Tract A into the Kit Carson Electric Cooperative/Tri-State substation located immediately adjacent to Tract A in

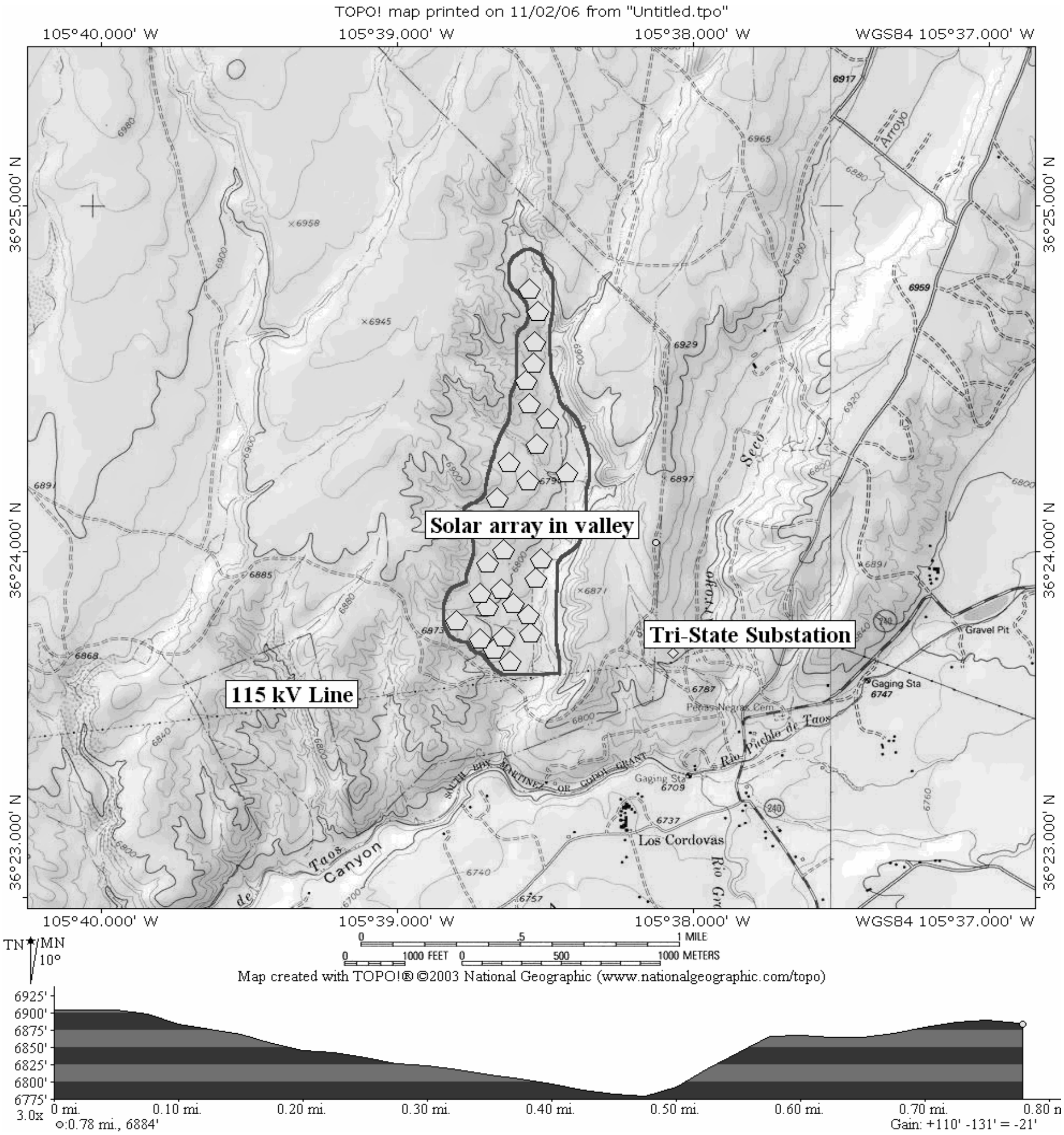
Los Cordovas. Kit Carson distributes about 485,000 MWHr/yr of electricity; they are allowed to purchase up to 5% of that amount from some source other than Tri-state under their all-requirements contract with Tri-state. Therefore, up to 24,250 MWhr./yr could be generated and sold to Kit Carson under this 5% "self-generation" option. Assuming 5.5 hrs per day of peak solar 325 days a year, there are 1788 hours of generation per year. Therefore, a 14 MW array on a 126 acre or larger parcel in Tract A could supply this 5 % share of the Kit Carson Electric Cooperative distribution load. There is a 200 acre "valley" within a half of a mile from the substation where these Stirling gensets could be located to screen them from residential neighborhoods in the vicinity. These solar parabolic dishes have a height of 35'; this valley in the otherwise rolling sagebrush terrain is about 100' in depth, and this elevation drop will enable the screening of the solar dishes. (See next page)

There is also the opportunity to sell power directly to Tri-State Generation & Transmission Cooperative in any amount they are willing to purchase through a power purchase agreement. The peak load for Kit Carson Electric Cooperative is 71 MW which would typically occur around 8 A.M. or 5 P.M. in the winter (based on load curve analysis of a neighboring electric cooperative, Springer Electric) The typical daytime demand would be in the range of 40 MW to 50 MW. Therefore, at some point in the next ten years the economics of emerging concentrated solar technologies could justify a 40 MW solar plant requiring around 400 acres of land. This would represent well less than one tenth of the area in Tract A. The 345 kV line and the 115 kV line owned by Tri-State G & T. traverses Tract A and creates a corridor where these arrays could be located. The 40 MW plant could connect directly to the Kit Carson Electric substation adjacent to Tract A rather than the 115 kV line, thereby avoiding substation costs and insuring that the power could be utilized directly by the Kit Carson distribution system for designated loads in the event of a regional grid failure.

Earning Potential of Tract A Projects

The annual generation from a 14 MW array would be about 24,000 MWhrs. Assuming a net profit to Taos Pueblo of 2 cents per kWhr. or $20 per MWh, then the project would earn $480,000./ year. Even at a modest profit of $15./MW the annual earnings would total $360,000. There would be additional earnings in terms of employment for tribal members.

The annual generation from a 45 MW array would be about 84,000 MWhrs. Based on the same assumptions above, the project would earn from $1,260,000. to $1,680,000 a year. The arrays can be repowered to operate for generations, creating a secure income stream for Taos Pueblo.


TOPO! map printed on 11/02/06 from "Untitled.tpo"
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WGS84 105°37.000' W
36°25.000' N
36°24.000' N
36°23.000' N
Solar array in valley
Tri-State Substation
115 kV Line
Los Cordovas
Taos Canyon
Rio Pueblo de Taos
Gravel Pit
Gaging Sta
Arroyo
Seco
0 .5 1 MILE
0 1000 FEET 0 500 1000 METERS
TN MN 10°
Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)
6925'
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0.30 mi.
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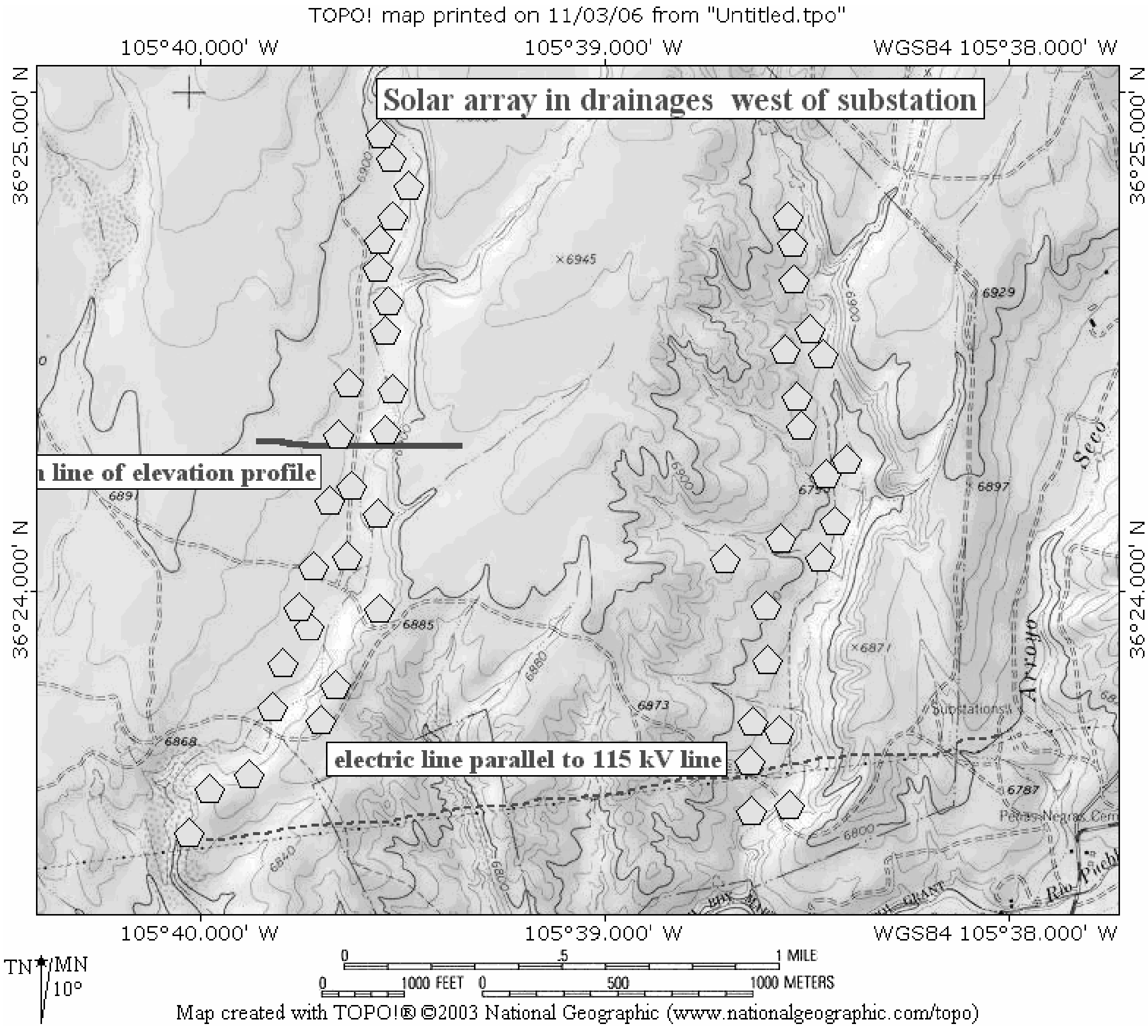
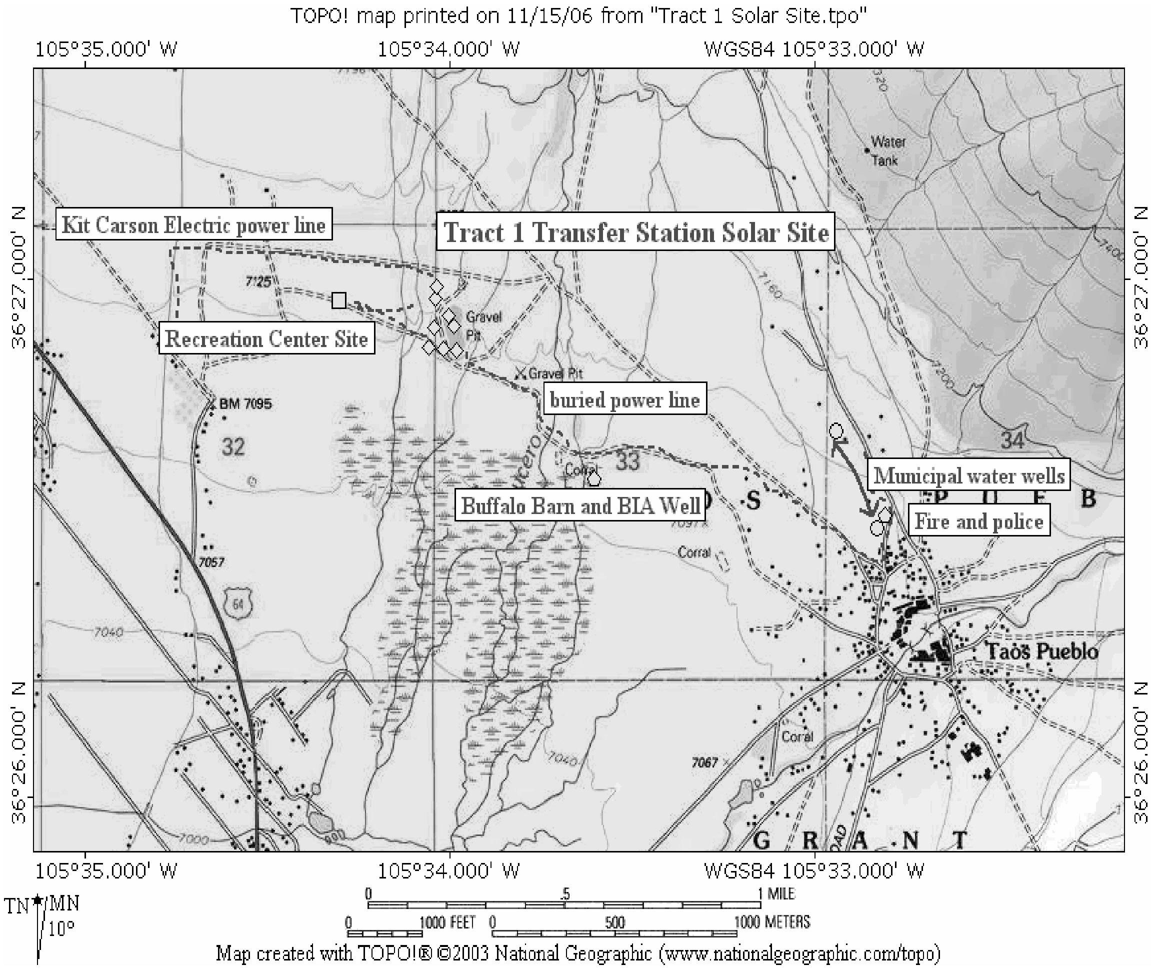
0.80 m
0.78 mi., 6884'
Gain: +110' -131' = -21'



Tract 1 Solar Site

Tract 1 is the designation for the old landfill and gravel pit site 1 1/2 miles west of the village where the transfer station is presently located. The parcel, which belongs to Taos Pueblo Utilities is 17 acres in size and includes an excavated area that could be an area for locating a solar array while preserving existing views. This would be of critical importance because this site is near the pow-wow grounds where traditional dancing and gatherings take place. By excavating a ten acre area in the old landfill, a one megawatt solar array could be located in a brown field site. The excavation of the landfill would remediate the site as a potential threat to water quality. The site is a terminus of a Kit Carson Electric buried distribution line and would allow for sale of excess power to the utility. This array could supply power (and hot water) to a planned recreation center to be located adjacent to Tract I. The array could also be connected via a buried power line to the Buffalo Barn, which is within 1/4 mile and is in need of power for a water well (already drilled), for operating tools, and for a possible meat storage facility. The buried line could continue to the village area to supply power to wells # 1 &2 of Taos Pueblo Utilities, the fire/police station, and to other loads.

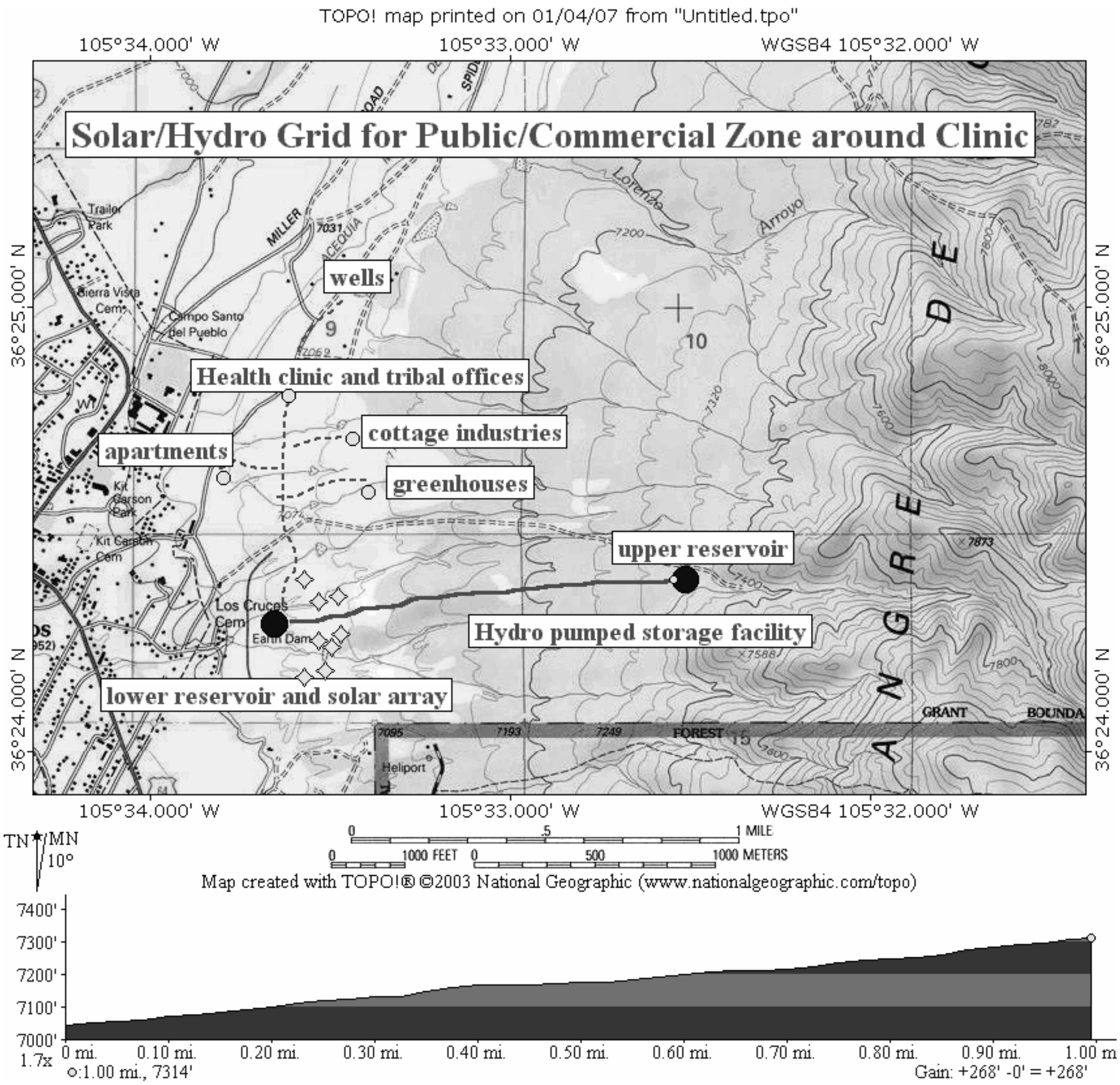


Solar/Pumped hydro at Health Clinic Area (Goat Springs Rd)

The area around the health clinic possess several features that indicates a good location renewable energy installation with 24 hr. power availability. The opportunity for a pumped storage facility is by virtue of the presence of an unused reservoir combined with adjacent foothills with a flat open area for an upper reservoir. This area is to the southern edge of the tribal community and the visual profile of solar will be lowered. Solar is controversial from a spiritual and visual point of view for some tribal elders. This particular area borders the edge of the Town of Taos, is some distance from the traditional village area, includes a number of tribal buildings including a health clinic, and would be an appropriate location for commercial operations such as cottage industries, greenhouses and fish farms. The land is also not divided into land assignments and therefore is available for larger scale developments either by tribal government or by business-minded tribal members.

The pumped storage reservoir would need to be only one acre in size and 15’ deep on average to hold enough water to generate 100 kW for 10 hours. This assumes a 250’ static head (see elevation profile above) and a flow of 8 cfs. The cost of such a reservoir using a Firestone geomembrane pond liner, including excavation and installation, would be less than $100,000.

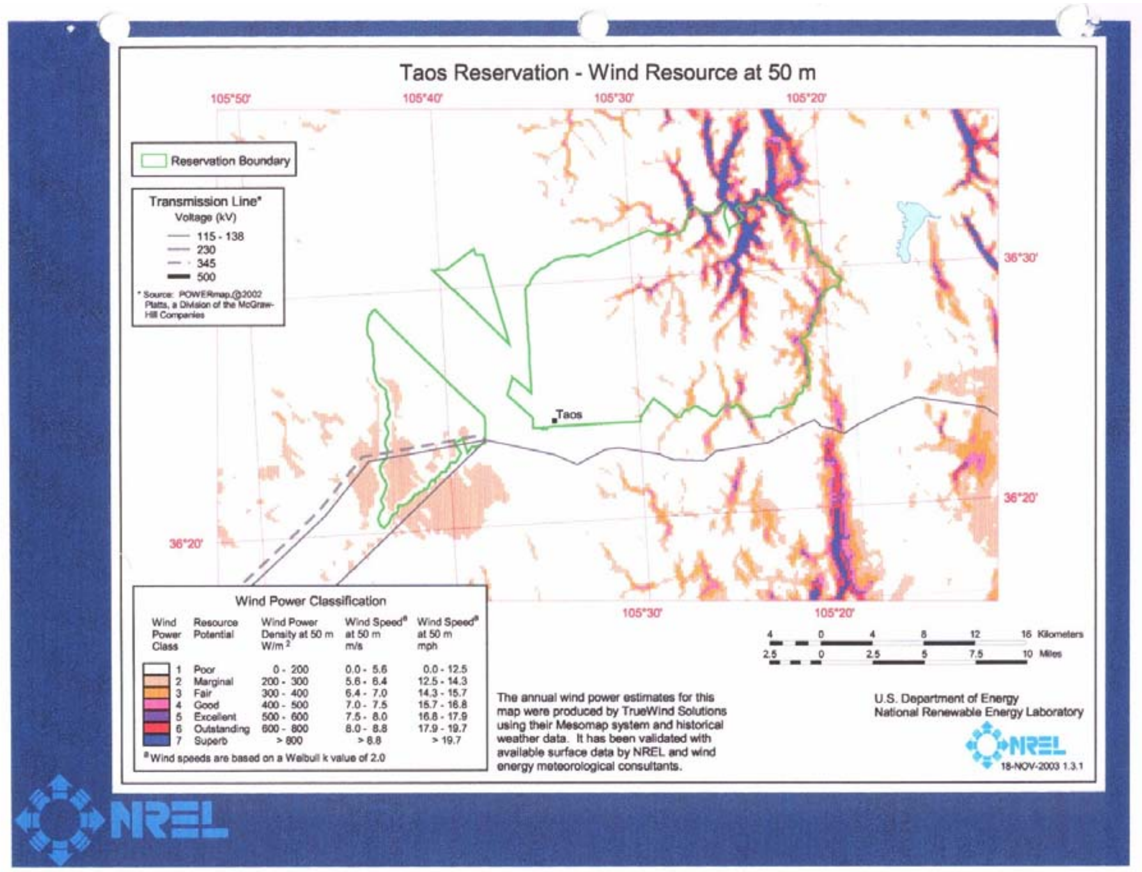
The solar array would have to be on the order of 300 kW to both supply 100 kW during the day while pumping the water from the lower reservoir to the upper reservoir for power during the night. The pumped hydro could also be utilized to supply a lower amount of power for a longer time to meet critical needs in the event of an emergency.



GREENHOUSES

Shown above is the subterranean heating and cooling system installed at the Red Willow Center. Fans inside the blue barrels pull air down from the ceiling area and pump the air through 4,000 feet of 4 inch perforated drainage pipe covered with a filter sock. The piping is buried in a 2' deep bed of crusher fines. During the day the hot air contacts the cooler ground and through phase change warm condensation transfers heat into the groundmass. At night the cool air inside the upper greenhouse is pumped through the piping in the warmer ground and heat is transferred back into the air and delivered through vents into the greenhouse. A testament of the effectiveness of the system was when a particularly severe cold snap killed off most plants in the greenhouse except those surrounding the vents. See appendix for data on monitoring of greenhouses with buried and ambient air sensors.

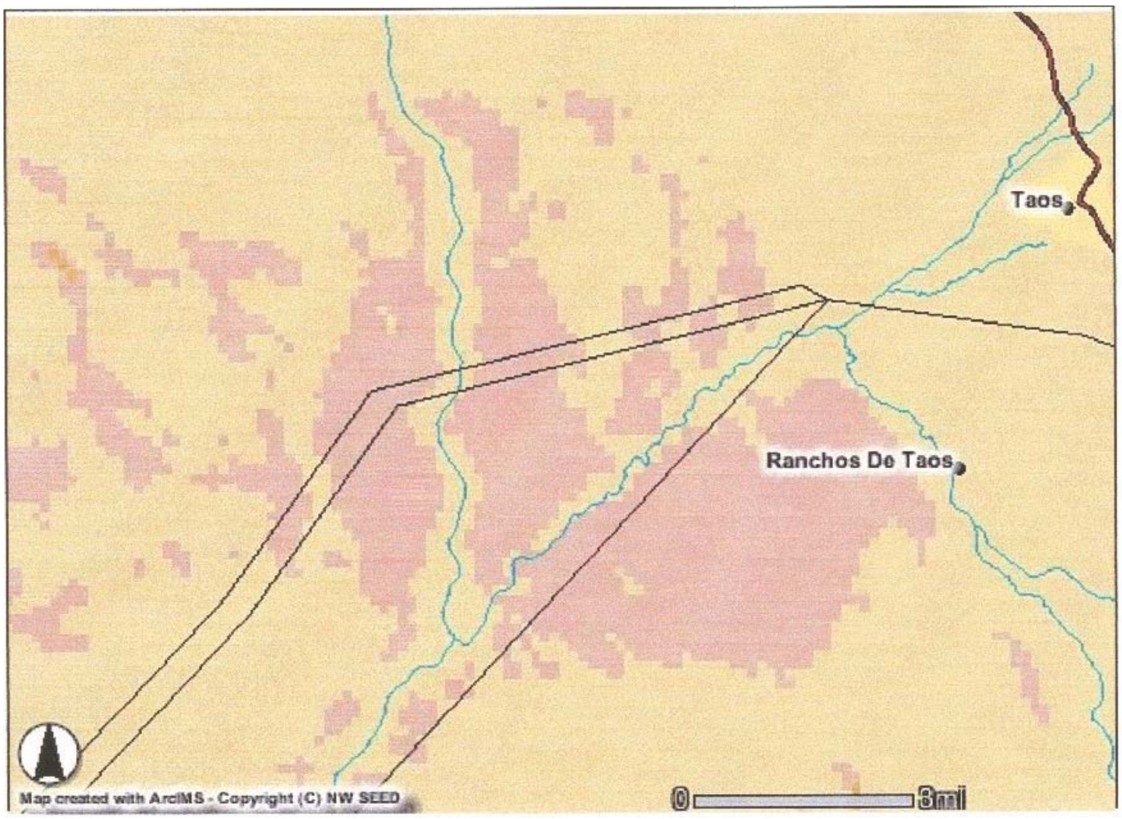
Wind



Aside from mountain ridges and slopes that are prominent in the scenic and traditional "view shed" of Taos Pueblo and Taos Valley, Tract A is the area always mentioned as an appropriate location for wind turbines. (See above: Tract A is the triangular area outlined in green and is traversed by transmission lines indicated in purple.) The map above shows that, at best, parts of Tract A are in wind power class 2 (marginal) with the remainder in class 1 (poor).

The airport borders Tract A, a very uniform topography of rolling sagebrush, and so airport data would be representative of what average wind speeds would be for most of Tract A. Wind data collected at the Taos Regional Airport for the year 2003 shows an average wind speed of 7 m.p.h. at 10 meters.   Data purchased from NOAA based on 12 years of wind speed measurements at the Taos Airport indicate 2003 was typical. The New Mexico Energy, Minerals and Natural Resources department did computer analysis projections that indicate that wind speeds could be in the 12 to 14-mph. range at 50 to 70 meters. Therefore the area is not considered economical for commercial scale wind turbines, which by rule of thumb need at least 16 mph. average wind speed. Another constraint is the proximity of the airport and FAA requirements that there be a horizontal distance of 100 ft. from a runway for every one foot of tower height. A 200 ft. wind turbine would need 20,000 ft. or almost 5 miles, excluding most of Tract A.

The map below from a State of New Mexico study reaffirms the class 2 rating of the Tract An area. On an anecdotal basis, this area is generally considered "windy", especially in the spring when clouds of dust move across this landscape. Small-scale wind turbines would be effective for pumping water for livestock. However, applying the power curve of small wind turbines to these conditions results in a capacity factor less than 17 %. Solar on the other hand has a capacity factor of 22%. Considering that solar requires less maintenance, the use of wind turbines would only be recommended on the basis that using wind is culturally more acceptable than solar at Taos Pueblo. Small wind turbines may be appropriate for residential use as long as noise and tower height was not an issue for neighbors.



V. CONCLUSIONS AND RECOMMENDATIONS

The most economical opportunities at the present time for renewable energy development at Taos Pueblo involve:

1. Harnessing an irrigation pipeline (to replace the Indian Ditch) with a hydroelectric turbine and installing a 2.9 mile buried power line to deliver power to tribal buildings and wells around the village, and to sell excess power to Kit Carson Electric Cooperative**.**

2. Installing an automated wood-fired boiler to supply heat/hot water to the Taos Pueblo/Picuris Health Clinic with a surplus to supply a planned housing development. Economic development made possible by low-cost energy would include commercial greenhouses and fish farms.

3. Long-term plan (beginning in 2010);

A. Install "concentrating" solar-electric array in Tract A to connect to the Tri-State Generation and Transmission Cooperative substation in Los Cordovas.

B. Install a 300 kW solar array in excavation at Tract 1 (transfer station/old landfill) to supply power and heat to Recreation Center and Buffalo Barn/ BIA well and for sale to Kit Carson. (Approx. $1 Million cost)

C. Install a 300 kW solar array in area southeast of Health Clinic (i.e. near unused reservoir site) A small pumped storage reservoir in the foothills connected to a water impoundment in the unused reservoir can store electricity from the solar array to create a on-demand renewable power supply.

D. The combination of the hydroelectric turbine and the two solar arrays at Tract 1 and the Health Clinic area would supply the equivalent of the roughly 3 million kWhrs. of power used at Taos Pueblo.

Other opportunities:

1. Small wind/solar installations for water pumping for Taos Pueblo
Utilities, livestock (i.e. Tracts A and B), and for residences not serviced by the Kit Carson Electric grid.

2. Installation of a wood-fired district heating systems to serve Taos Pueblo Day School, Community Center and Health and Community Services.

3. Planting of biodiesel crops such as sunflowers and canola, and operating cottage industry-scale oil seed press and biodiesel processing unit. Supply transportation fuel for critical services (WarChiefs trucks, Roads equipment, Fire and Police, and power generators)

4. Greenhouse nursery to supply seedlings for replanting Encebado while harvesting fire-kill for heating commercial greenhouse complex. (i.e. south of Health Clinic area)

Not Recommended:

Commercial scale wind turbines would only be economical on the high mountain ridge on the south boundary (parallel to Taos Canyon) and connecting to the Tri-State 115 kV transmission line for sale of the electricity. The impacts on the scenery of the mountains would not be acceptable in general. Tract A has less economical wind speeds and the proximity of the airport rules out higher turbine towers in all but the southwest corner of Tract A.

Creation of an independent utility/grid at Taos Pueblo would require extensive capital and job training with marginal benefits. It is advisable to work with Kit Carson Electric Cooperative as a buyer of excess generation and as a reliable source of "back-up" power to any Taos Pueblo direct use project.

Recommended Strategies

1. The hydroelectric turbine for the Indian Ditch pipeline can be negotiated and paid for through the water rights settlement. Alternative funding approaches would include a commercial loan through the BIA Loan Guaranty, Insurance and Interest Subsidy Program ($10 million cap for tribal owned business). The operation and maintenance of the turbine and the mini-grid can be through Taos Pueblo Utilities thereby helping to pay the salaries of existing staff and generate funds for future improvements and projects.

2. The district heating system for the Clinic area (Goat Springs Rd.) can be financed through a supply contract with the Indian Health Service. Initial capital can be through the BIA Loan Guaranty, Insurance and Interest Subsidy Program. Wood supplied for the boiler can be through the WarChief office, thereby creating an additional income stream for that office.

The siting of a district-heating system and a solar-array with pumped hydro storage at the Goat Springs Rd. area would suggest this area as appropriate for tribal commercial development as part of a land use plan. (The proximity of this area to the town of Taos and conversely, the distance from the village/traditional area may also support this land use.)

3. The sale of electricity to Kit Carson Electric can be negotiated through the 5% self-generation clause in Kit Carson's all-requirements power agreement with Tri-State Generation & Transmission Cooperative (Tri-State is the wholesale supplier of power to Kit Carson Electric). Beyond the approximate 3 Megawatt capacity allowed under that clause, an agreement for above 3 megawatts in generation would have to be negotiated with Tri-State (i.e. the 60 MW array in Tract A). An additional source of leverage in that negotiation can be the Western Area Power Authority (WAPA), which now contracts, with Tri-State for the delivery of the WAPA power allotment to Taos Pueblo.
The power can also be sold under the auspices of PURPA (Public Utilities Regulatory Policy Act) as a qualifying facility. Tri-state has to purchase the power under federal law, at the "avoided cost of power" to Tri-State. Historically this price has been very low, but due to the increasing cost of power, using PURPA may guarantee adequate revenues to pay for project

development costs. Under the Energy Policy Act of 2005, PURPA was amended so that the requirement for a utility (Tri-State) to purchase power from a qualifying facility (Taos Pueblo) would only apply in areas that do not have competitive market conditions for power. In a conversation with Mr. Prassad of the New Mexico Public Regulatory Commission, it was determined that New Mexico does not have these conditions, therefore PURPA rules still apply to the Taos Pueblo area.

Summary of Opportunity

The building of energy infrastructure using renewable resources such as stream flow, forest wood, and solar can create a reliable, inexhaustible source of electricity and heat under the control of Taos Pueblo and not under the control of outside companies and conditions. This energy infrastructure will keep utility bill dollars circulating inside the community while creating salaries for tribal members operating and managing the energy installations and supplying wood from the forests. The harvesting of that wood will help prevent catastrophic wildfires like the Encebado Fire and generally improve forest health. And when the power goes down, electricity is "priceless in a crisis". There is also the importance of acting in way that protects the earth rather than harming the environment. The use of emission-free or low emission energy sources is taking a path of responsibility in regards to global warming and clean air and water.

The future of energy prices is one of spiraling increases. By harnessing renewable resources, Taos Pueblo can protect itself from rising energy bills and shortages or interruptions. By the same token, these higher prices create opportunity for economic development by creating a market for electricity that did not exist before. Taos Pueblo can use the solar resources of Tract A to become an energy supplier. The income from a 60 MW facility can be substantial and more reliable than government funding. The availability of low-cost heat from biomass means that commercial greenhouses and fish farms at Taos Pueblo can become a major job and revenue generator. These kinds of industrial and business operations also require the kind of education and training that tribal youth can seek as part of a career path that leads right back home to the Pueblo. Energy can be the foundation of economic development and there is no end to these renewable resources.

The use of the water, forest, sun and soil on the lands of Taos Pueblo to meet basic needs is at the heart of the history of the Taos Pueblo. The development of these energy projects can deepen the connection to the land while enhancing sovereignty and the ability to be self-sufficient. The equipment in energy projects such as the hydroelectric turbine on the irrigation piping have a lifecycle of 50 to 100 years and can be replaced on a regular basis to continue operating for centuries. Renewable energy is a forever fuel. This feasibility study presents a strategic plan that is not only for the present but also for generations and generations to come.

VI. DRAFT OF BUSINESS PLAN

Indian Ditch Hydroelectric Project

Executive Summary

Taos Pueblo is planning the rehabilitation of the irrigation ditch and pipe system to be financed by a water rights settlement presently being negotiated through the Federal government. HKM Engineering of Billings, Montana has been performing the planning of this irrigation rehabilitation. HKM was contracted through the Taos Pueblo Renewable Energy program to assess the hydroelectric potential of utilizing seven pipeline projects slated for construction as part of the rehabilitation of the irrigation ditch system. The study identified "Turbine B" on the Indian Ditch as the most promising opportunity.

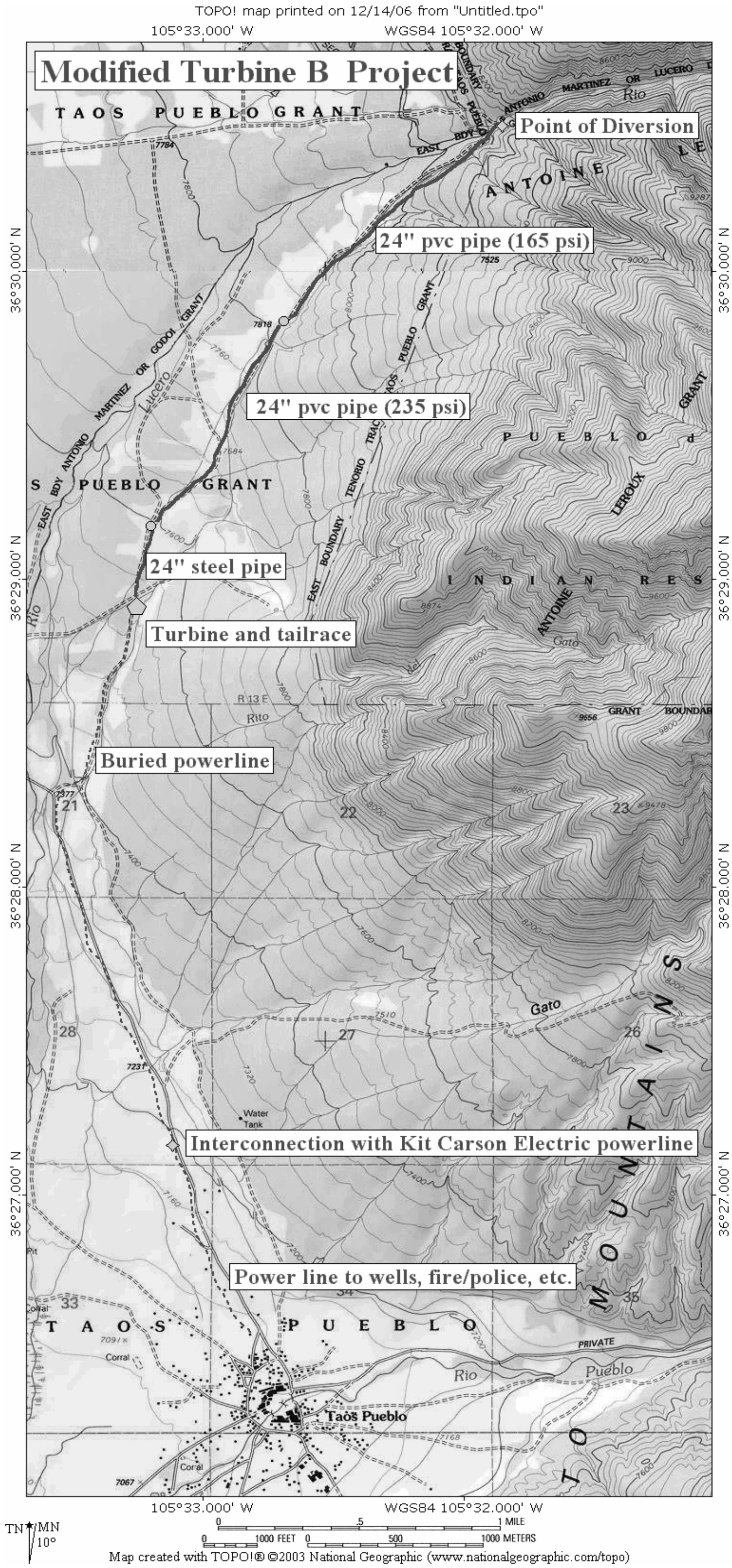
Presently the Indian Ditch consists of a length of culvert pipe followed by an open concrete lined ditch totaling over two miles. The ditch supplies water to a complex of other irrigation ditches and can therefore be considered a central artery of the irrigation system. It presently loses a lot of water due to leaking and replacement with a 27" to 24" pipeline is being planned. Because of the almost 600 ft. elevation change there is tremendous static head created in a closed pipe system and pressure reduction valves will have to be utilized to "burn off " this force. A hydroelectric turbine can accomplish the same dissipation of energy while generating electricity. The hydroelectric study shows there is an opportunity to place a turbine ranging in size from 212 kW for average flows to 579 kW for maximum flows. By installing the maximum flow turbine with a capacity of 579 kW, rather than the average flow turbine rated at 212 kW, the increase of 472,968 kWhr/yr. will generate at a minimum an additional $1.2 million in revenues over the 40 yr. life of the turbines. This would more than pay the incremental cost of the larger turbine.

However, environmental impacts of diverting a higher percentage of winter flows from a two-mile stretch of the Rio Lucero must be considered.

The single 570kW turbine will generate the equivalent of over 60% of all the electricity used at the Pueblo. (Estimated at 2,600,000 kWhr/yr. in 2004. Based on the worst case scenario of the pending Federal water settlement not paying for the incremental cost of the hydroelectric, the project can recover all capital costs and O & M costs in the 40 year life of the turbines, as well as generate $5 Million in profits. The supply pipe or penstock will have a life cycle of 80 to 100 years, meaning that after 40 years the turbine, generator and electronic controls can be replaced, and another 40 years of even higher earnings can be reaped. The priceless benefit to Taos Pueblo is a secure source of power flowing down from mountain, so to speak, that will be directly supporting water supply, fire and police protection, food storage, and many other tribal operations.

B. Resource Assessment

The stream flow availability for the proposed hydroelectric installation is thoroughly assessed in the HKM Engineering study for the Turbine B option. The water flow available for hydroelectric generation is based on 52 years of USGS stream data (1935-1988) measured at a gauge at the diversion on the Rio Lucero that supplies the Indian Ditch. There is a decree allocation of 46.7% of that flow to Taos Pueblo and 56% of that volume is allocated to the Indian Ditch. The maximum flow available for supplying the turbine, 17 cubic feet per second (cfs), is defined by the size of the pipeline required to supply irrigation water to the acreage serviced by the Indian Ditch. Under the pending water settlement, there is the potential to use most of the winter flows (November through March) as well for hydropower generation. The HKM study assumes use of 90% of winter flow for diversion for hydroelectric generation. This amount can be decreased in order to keep more water in the Rio Lucero streambed if necessary with minimal impact on annual generation. The average flow is 6 cfs. The concept here is to build a pipeline that serves both hydroelectric and irrigation needs. Therefore, the turbine should be sized to fit the pipeline and water flows that will be needed for irrigation. On typical hydro projects the average flows are utilized to avoid excessive costs on penstock. In this instance the pipeline needs to be large enough to meet peak irrigation needs. The incremental cost of a larger turbine is a small part of the total system.



TOPO! map printed on 12/14/06 from "Untitled.tpo"
105°33.000' W
WGS84 105°32.000' W
Modified Turbine B Project
Point of Diversion
24" pvc pipe (165 psi)
24" pvc pipe (235 psi)
24" steel pipe
Turbine and tailrace
Buried powerline
Interconnection with Kit Carson Electric powerline
Power line to wells, fire/police, etc.
TAOS PUEBLO GRANT
Taos Pueblo
36°30.000' N
36°29.000' N
36°28.000' N
36°27.000' N
TN MN 10°
0 .5 1 MILE
0 1000 FEET 0 500 1000 METERS
Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

C. Load Assessment and Export Market

The direct load that can be serviced with the shortest transmission line is the Taos Pueblo village area including tribal offices, schools, and municipal water wells. The table below identifies these loads and the approximate amount of power typically used. A "mini-grid consisting of buried distribution lines can bring the hydro power directly to these buildings or "loads". See IV below for further detail.

ELECTRIC LOAD IN TAOS PUEBLO VILLAGE AREA SERVICED BY "MINI-GRID" INCLUDING ADDITIONAL CAPACITY FOR MEAT STORAGE FACILITY

North		
	Annual Kwh	
T.P. Utility Wells	44,486	
Law Enforcement	21,588	
Seniors	14,522	
Environment	11,458	
Tribal Government	24,883	
	116,937	
South		
Community Center	10,826	
Day School/Headstart	146,933	
Health and Human Services	23,315	
	181,074	
Total Annual kWh	298,011	
Meat/food Storage Facility (3,000 sq. ft. and 48-hp. loads)	105,000	
Total Annual Demand	403,011 kWh	
Avoided cost @ $0.069/kWh		$27,807. /yr.
Total Generation of 579 kW turbine	1,857,996 kWh	
Available for export to Kit Carson Electric	1,454,985 kWh	
Sale price @ $.065/kWh (present Tri-state wholesale price of $0.055/kWh + one cent/kWh for Renewable Energy Credit)		$94,574./yr.
Total Revenue/Avoided Cost		$122,381./yr. ($0.0659/kWh)

The amount of power not utilized by the direct loads on the "mini-grid" would be available for export sales through an interconnection to the Kit Carson Electric Cooperative distribution system. Kit Carson Coop has an all-requirements wholesale power contract with Tri-State Generation and Transmission Cooperative that supplies power to Kit Carson Coop. A clause in that contract (Board Rule #110) allows Kit Carson to self-generate or purchase up to 5 % of the total power use by the Kit Carson Coop system. This amounts to about 3 MW of capacity; a 500 kW hydroelectric turbine would therefore be well within the 5% of total system demand.

An additional export option is to become a qualifying facility under PURPA rules. Kit Carson would pass through the PURPA obligation to Tri-State G &T. Under PURPA rules (as amended by the Energy Policy Act of 2005), given there is no competitive market in northern New Mexico, Tri-State would have to purchase the power from Taos Pueblo at the "avoided cost of energy". Historically this "avoided cost" has been very low, but presently Tri-State is having to build new generation capacity that costs more than 5 cents/kWh.

Although it would be possible to sell the power to a buyer further away, there would be wheeling costs through the Kit Carson system and the Tri-State transmission system. This creates a "pancaking" of charges that become prohibitive for sales. However, given the increasing price of electricity on the wholesale market, at some point the added transmission costs can be afforded in order to export the power to more distant markets.

With a net metering arrangement in place with Kit Carson, any amount of power in the "mini-grid" connection not being utilized by the building or well will turn the meter backwards essentially banking kilowatt hours. When electricity is needed from the grid then the meter runs forward, using the kilowatts that had been delivered from the "mini-grid" earlier. However, there is a 10 kW limit on the size of a renewable energy generator that can qualify for the net metering arrangement. Although the proposed hydroelectric turbine would have a 500 kW capacity, the amount of power allowed onto the mini-grid could be limited to be equivalent to 100 kW and represent the supply to ten loads (10 x 10 kW). This strategy would be effective if there is difficulty contracting a power purchase agreement for selling excess power to Kit Carson or Tri-State.

D. Transmission and interconnection

The distance from the proposed turbine site to the nearest point of the Kit Carson Coop distribution line (buried) is about 2.4 miles along Rio Lucero Rd. In a conversation with an engineer at Kit Carson, the line along Rio Lucero Rd. was identified as a large size conductor capable of handling a 200 kW generator. Further line studies will be necessary to locate the best interconnection for a 500 kW generator. The interconnection can also be closer in near the village. In the event of a local or regional grid failure this interconnection will have a disconnect switch activated that will keep power from going on to the disabled Kit Carson grid. At that point the "mini-grid" can continue to operate supplying electricity to tribal buildings and wells. The "mini-grid" servicing tribal buildings and wells in the village area would interface with the existing connection to the Kit Carson Electric Cooperative grid presently servicing the tribal buildings and wells. Therefore the hydroelectricity becomes the main source of power with the grid as "back-up".

E. Technology Analysis

The HKM study includes an excellent description of technology options in hydroelectric turbines repeated below:

The Pelton turbine's ability to operate at only 10% of capacity allows it to produce at 50 kW. In the 52 years of recorded data, the stream flows only dipped below a 50 kW generation potential in four months.

The option to operate independently of the grid requires an additional set of controls making the system both asynchronous and synchronous. The will add cost to the project, however there is a high value of having electricity for critical services in the event of the failure of the grid. The additional electronic controls enables the hydroelectric to continue delivering power locally. Otherwise, the turbine needs the grid to be operating in order to incite the turbine generator with a signal.

The choice of pipe for the penstock is critical as it represents the largest part of the cost. The use of high-pressure PVC is essential to lower the costs of the penstock. The Larsen Bay project on Kodiak Island is very similar in size to the proposed Indian Ditch turbine. The hydroelectric project has a 6,062-foot steel and PVC pipe penstock, a 140-foot wide, 14 feet high earth filled dam and has a run-of-river, 475-kilowatt Pelton turbine/generator. The elevation difference is approximately 600 feet. The project has been in operation since 1982 and is a good example of the use of PVC and steel in combination for penstocks.

F. Economic Analysis

The HKM Engineering Study uses costs for steel pipe in areas where lower pipe pressures in the majority of the penstock would allow for use of water main grade PVC pipe. The C905 grade water main pipe comes with a gasket connection that also lowers installation cost (no welding). The HKM study uses a cost of $190. per foot of installed steel pipe. The use of this PVC pipe, results in a cost of 103. /ft for the penstocks. This lowers the cost of the Turbine B penstock by $87. /ft. for 12,166 ft. totaling $1,058,442 in savings.

The "Modified Turbine B Project" utilizes from the point of diversion 6,743 ft. of 24 " C905-DR 25 pipe with a pressure rating of 165 psi, followed by 5,403 ft. of 24" C905-DR 18 pipe rated at 235 psi, and then 1,320 ft. of 24" steel pipe where static head exceeds 235 psi.

The project cost would then comprise the following:

6,743 ft. of 24 " C905-DR 25 pipe, installed @ $90. /ft.	$606,870.
5,403 ft. of 24" C905-DR 18 pipe, installed @ $106. /ft.	572,718.
1,320 ft. of 24" steel pipe, installed @ $ 180. ft.	237,600.
	1,417,188.

Total penstock	1,417,188.
Turbine, controls and civil works, engineering @ $1,200. /kW x 579 kW	868,500.
Project management	150,000.
	2,243,688.
Offset of cost of irrigation pipe and pressure reduction valves (as estimated by HKM)	-1,213,908.

. The additional 367 kW capacity will only add about $220,000. in turbine costs (cost estimates from Canyon Hydro).

Incremental cost of hydroelectric	1,221,780.
2.9-mile power line	160,000.
Mini-grid and utility interconnection	89,500.
Total cost of project	1,471,280.

Incremental "mini-grid " cost		$89,500.
4,000 ft buried line	$38,000.	
9 utility interconnection panels	$41,500	
Engineering	10,000	

The spreadsheet analysis below shows that the combination of avoided expenditures for electricity and export sales to the local utility can pay off the capital costs of the hydroelectric installation, pay for operation and maintenance, and generate a profit based on the ever increasing market value of electricity. The initial sale price of $0.0659 is based on the weighted average of the wholesale price that Kit Carson Electric pays for power from Tri-State plus the renewable energy credit value.

Total Annual Demand in Village Area		403,011 kWh
Avoided cost @ $0.069/kWh		$27,807./yr.
Total Generation of 579 kW turbine	1,857,996 kWh	
Available for export to Kit Carson Electric		1,454,985 kWh
Sale price @ $.065/kWh (present Tri-state wholesale price of $0.055/kWh + one cent/kWh for Renewable Energy Credit)		$94,574./yr.
Total Revenue/Avoided Cost		$122,381./yr. ($0.0659/kWh)

The project can be financed through a 20-year commercial loan with loan guarantees and interest subsidy supplied by the BIA through the Loan Guarantee and Interest Subsidy program. Under that program, Taos Pueblo would approach a commercial lender, which would then apply to the BIA for the loan guarantees, which cover 90% of the loan. The program will pay all interest over 4 ½ % for the first 1 to 5 years, and then 1 1/1 to 2 points off of prime rate. In a phone discussion with Jerry Ryburn, a contractor for the BIA loan guarantee program in Albuquerque, it was his opinion that this hydroelectric project would receive the highest rating from the BIA in regards to meeting the test of benefits to the community. He also indicated that Taos Pueblo would not have to secure or collateralize the loan with anything other than the equipment being purchased.

The spreadsheet below shows that the project will earn $6 million over the 40 yr. life of the turbines (which can operate for up to 50 years according to Canyon Hydro, a manufacturer of pelton turbines). In addition, there is the income to the tribe from the creation of jobs operating the turbine.

Year	Cost of Capital	kWhr./yr.	$/kW/hr	Escalator	Earning	O+M	Net Profit
1	111,696.00	1,857,996	$0.0659	4.0%	$122,441.94	34,000	-23,254
2	111,696.00	1,857,996	$0.0685	4.0%	$127,339.61	35,360	-19,716
3	111,696.00	1,857,996	$0.0713	4.0%	$132,433.20	36,774	-16,037
4	111,696.00	1,857,996	$0.0741	4.0%	$137,730.53	38,245	-12,211
5	111,696.00	1,857,996	$0.0771	4.0%	$143,239.75	39,775	-8,231
6	121,440.00	1,857,996	$0.0802	4.0%	$148,969.34	41,366	-13,837
7	121,440.00	1,857,996	$0.0834	4.0%	$154,928.11	43,021	-9,533
8	121,440.00	1,857,996	$0.0867	4.0%	$161,125.24	44,742	-5,056
9	121,440.00	1,857,996	$0.0902	4.0%	$167,570.24	46,531	-401
10	121,440.00	1,857,996	$0.0938	4.0%	$174,273.05	48,393	4,440
11	121,440.00	1,857,996	$0.0975	4.0%	$181,243.98	50,328	9,476
12	121,440.00	1,857,996	$0.1015	4.0%	$188,493.74	52,341	14,712
13	121,440.00	1,857,996	$0.1055	4.0%	$196,033.49	54,435	20,158
14	121,440.00	1,857,996	$0.1097	4.0%	$203,874.82	56,612	25,822
15	121,440.00	1,857,996	$0.1141	4.0%	$212,029.82	58,877	31,713
16	121,440.00	1,857,996	$0.1187	4.0%	$220,511.01	61,232	37,839
17	121,440.00	1,857,996	$0.1234	4.0%	$229,331.45	63,681	44,210
18	121,440.00	1,857,996	$0.1284	4.0%	$238,504.71	66,229	50,836
19	121,440.00	1,857,996	$0.1335	4.0%	$248,044.90	68,878	57,727
20	121,440.00	1,857,996	$0.1388	4.0%	$257,966.69	71,633	64,894
21	0.00	1,857,996	$0.1444	4.0%	$268,285.36	74,498	193,787
22	0.00	1,857,996	$0.1502	4.0%	$279,016.77	77,478	201,539
23	0.00	1,857,996	$0.1562	4.0%	$290,177.45	80,577	209,600
24	0.00	1,857,996	$0.1624	4.0%	$301,784.54	83,800	217,984
25	0.00	1,857,996	$0.1689	4.0%	$313,855.93	87,152	226,704
26	0.00	1,857,996	$0.1757	4.0%	$326,410.16	90,638	235,772
27	0.00	1,857,996	$0.1827	4.0%	$339,466.57	94,264	245,203
28	0.00	1,857,996	$0.1900	4.0%	$353,045.23	98,035	255,011
29	0.00	1,857,996	$0.1976	4.0%	$367,167.04	101,956	265,211
30	0.00	1,857,996	$0.2055	4.0%	$381,853.72	106,034	275,820
31	0.00	1,857,996	$0.2137	4.0%	$397,127.87	110,276	286,852
32	0.00	1,857,996	$0.2223	4.0%	$413,012.99	114,687	298,326
33	0.00	1,857,996	$0.2312	4.0%	$429,533.51	119,274	310,260
34	0.00	1,857,996	$0.2404	4.0%	$446,714.85	124,045	322,670
35	0.00	1,857,996	$0.2500	4.0%	$464,583.44	129,007	335,577
36	0.00	1,857,996	$0.2600	4.0%	$483,166.78	134,167	349,000
37	0.00	1,857,996	$0.2704	4.0%	$502,493.45	139,534	362,960
38	0.00	1,857,996	$0.2813	4.0%	$522,593.19	145,115	377,478
39	0.00	1,857,996	$0.2925	4.0%	$543,496.91	150,920	392,577
40	0.00	1,857,996	$0.3042	4.0%	$565,236.79	156,956	408,280
						3,230,868	**6,024,161**

BIA 20 yr. Loan

Hydroelectric equipment and civil works @ $1,500 kW

Assumptions: 4.5% interest rate for 5 years and 5.5% for 15 years

A grant of $108,000. or funds from the water settlement would have to pay for the deficit during the first 8 years of operation. The operation and maintenance of the turbine and the mini-grid can be through Taos Pueblo Utilities thereby helping to pay the salaries of existing staff and generate funds for future improvements and projects. The allowance for O & M may be high considering existing personnel can oversee much of the operation and equipment is still new. This amount could be lowered to eliminate most of the deficit in the first years. The spreadsheet below shows that this would reduce the grant requirements to pay the deficit to $33,000.

579 kW Hydroelectric Project at Turbine B -With Irrigation Offset, BIA Loan

Year	Cost of Capital	kWhr./yr.	$/kW/hr	Escalator	Earning	O+M	Net Profit
1	111,696.00	1,857,996	$0.0659	4.0%	$122,441.94	25,000	-14,254
2	111,696.00	1,857,996	$0.0685	4.0%	$127,339.61	26,000	-10,356
3	111,696.00	1,857,996	$0.0713	4.0%	$132,433.20	27,040	-6,303
4	111,696.00	1,857,996	$0.0741	4.0%	$137,730.53	28,122	-2,087
5	111,696.00	1,857,996	$0.0771	4.0%	$143,239.75	29,246	2,297
6	121,440.00	1,857,996	$0.0802	4.0%	$148,969.34	30,416	-2,887
7	121,440.00	1,857,996	$0.0834	4.0%	$154,928.11	31,633	1,855
8	121,440.00	1,857,996	$0.0867	4.0%	$161,125.24	32,898	6,787
9	121,440.00	1,857,996	$0.0902	4.0%	$167,570.24	34,214	11,916
10	121,440.00	1,857,996	$0.0938	4.0%	$174,273.05	35,583	17,250
11	121,440.00	1,857,996	$0.0975	4.0%	$181,243.98	37,006	22,798
12	121,440.00	1,857,996	$0.1015	4.0%	$188,493.74	38,486	28,567
13	121,440.00	1,857,996	$0.1055	4.0%	$196,033.49	40,026	34,568
14	121,440.00	1,857,996	$0.1097	4.0%	$203,874.82	41,627	40,808
15	121,440.00	1,857,996	$0.1141	4.0%	$212,029.82	43,292	47,298
16	121,440.00	1,857,996	$0.1187	4.0%	$220,511.01	45,024	54,047
17	121,440.00	1,857,996	$0.1234	4.0%	$229,331.45	46,825	61,067
18	121,440.00	1,857,996	$0.1284	4.0%	$238,504.71	48,698	68,367
19	121,440.00	1,857,996	$0.1335	4.0%	$248,044.90	50,645	75,959
20	121,440.00	1,857,996	$0.1388	4.0%	$257,966.69	52,671	83,855
21	0.00	1,857,996	$0.1444	4.0%	$268,285.36	54,778	213,507
22	0.00	1,857,996	$0.1502	4.0%	$279,016.77	56,969	222,048
23	0.00	1,857,996	$0.1562	4.0%	$290,177.45	59,248	230,929
24	0.00	1,857,996	$0.1624	4.0%	$301,784.54	61,618	240,167
25	0.00	1,857,996	$0.1689	4.0%	$313,855.93	64,083	249,773
26	0.00	1,857,996	$0.1757	4.0%	$326,410.16	66,646	259,764
27	0.00	1,857,996	$0.1827	4.0%	$339,466.57	69,312	270,155
28	0.00	1,857,996	$0.1900	4.0%	$353,045.23	72,084	280,961
29	0.00	1,857,996	$0.1976	4.0%	$367,167.04	74,968	292,199
30	0.00	1,857,996	$0.2055	4.0%	$381,853.72	77,966	303,887
31	0.00	1,857,996	$0.2137	4.0%	$397,127.87	81,085	316,043
32	0.00	1,857,996	$0.2223	4.0%	$413,012.99	84,328	328,685
33	0.00	1,857,996	$0.2312	4.0%	$429,533.51	87,701	341,832

34	0.00	1,857,996	$0.2404	4.0%	$446,714.85	91,210	355,505
35	0.00	1,857,996	$0.2500	4.0%	$464,583.44	94,858	369,726
36	0.00	1,857,996	$0.2600	4.0%	$483,166.78	98,652	384,515
37	0.00	1,857,996	$0.2704	4.0%	$502,493.45	102,598	399,895
38	0.00	1,857,996	$0.2813	4.0%	$522,593.19	106,702	415,891
39	0.00	1,857,996	$0.2925	4.0%	$543,496.91	110,970	432,527
40	0.00	1,857,996	$0.3042	4.0%	$565,236.79	115,409	449,828
						2,375,638	**6,879,390**

Assumptions: 4.5% interest rate for 5 yrs. And 5.5 % for 15 yrs.
BIA 20 yr. Loan
Hydroelectric equipment and civil works @ $1,500 kW

The pipeline will have a life expectancy of up to 100 years and therefore allows for a "repowering" after 40 years with a new turbine, generator and electronic controls. Therefore, in the second stage, the earnings will be much greater than $6 million.

Value of project repowered for additional 40 years (present dollars)

579 kW Hydroelectric Project at Turbine B -With Irrigation Offset, BIA Loan- Repowering

Year	Cost of Capital	kWhr./yr.	$/kW/hr	Escalator	Earning	O+M	Net Profit
1	73,068.00	1,857,996	$0.0659	4.0%	$122,441.94	25,000	24,374
2	73,068.00	1,857,996	$0.0685	4.0%	$127,339.61	26,000	28,272
3	73,068.00	1,857,996	$0.0713	4.0%	$132,433.20	27,040	32,325
4	73,068.00	1,857,996	$0.0741	4.0%	$137,730.53	28,122	36,541
5	73,068.00	1,857,996	$0.0771	4.0%	$143,239.75	29,246	40,925
6	73,068.00	1,857,996	$0.0802	4.0%	$148,969.34	30,416	45,485
7	73,068.00	1,857,996	$0.0834	4.0%	$154,928.11	31,633	50,227
8	73,068.00	1,857,996	$0.0867	4.0%	$161,125.24	32,898	55,159
9	73,068.00	1,857,996	$0.0902	4.0%	$167,570.24	34,214	60,288
10	73,068.00	1,857,996	$0.0938	4.0%	$174,273.05	35,583	65,622
11	73,068.00	1,857,996	$0.0975	4.0%	$181,243.98	37,006	71,170
12	73,068.00	1,857,996	$0.1015	4.0%	$188,493.74	38,486	76,939
13	73,068.00	1,857,996	$0.1055	4.0%	$196,033.49	40,026	82,940
14	73,068.00	1,857,996	$0.1097	4.0%	$203,874.82	41,627	89,180
15	73,068.00	1,857,996	$0.1141	4.0%	$212,029.82	43,292	95,670
16	73,068.00	1,857,996	$0.1187	4.0%	$220,511.01	45,024	102,419
17	73,068.00	1,857,996	$0.1234	4.0%	$229,331.45	46,825	109,439
18	73,068.00	1,857,996	$0.1284	4.0%	$238,504.71	48,698	116,739
19	73,068.00	1,857,996	$0.1335	4.0%	$248,044.90	50,645	124,331
20	73,068.00	1,857,996	$0.1388	4.0%	$257,966.69	52,671	132,227
21	0.00	1,857,996	$0.1444	4.0%	$268,285.36	54,778	213,507
22	0.00	1,857,996	$0.1502	4.0%	$279,016.77	56,969	222,048
23	0.00	1,857,996	$0.1562	4.0%	$290,177.45	59,248	230,929
24	0.00	1,857,996	$0.1624	4.0%	$301,784.54	61,618	240,167

25	0.00	1,857,996	$0.1689	4.0%	$313,855.93	64,083	249,773
26	0.00	1,857,996	$0.1757	4.0%	$326,410.16	66,646	259,764
27	0.00	1,857,996	$0.1827	4.0%	$339,466.57	69,312	270,155
28	0.00	1,857,996	$0.1900	4.0%	$353,045.23	72,084	280,961
29	0.00	1,857,996	$0.1976	4.0%	$367,167.04	74,968	292,199
30	0.00	1,857,996	$0.2055	4.0%	$381,853.72	77,966	303,887
31	0.00	1,857,996	$0.2137	4.0%	$397,127.87	81,085	316,043
32	0.00	1,857,996	$0.2223	4.0%	$413,012.99	84,328	328,685
33	0.00	1,857,996	$0.2312	4.0%	$429,533.51	84,328	345,206
34	0.00	1,857,996	$0.2404	4.0%	$446,714.85	84,328	362,387
35	0.00	1,857,996	$0.2500	4.0%	$464,583.44	84,328	380,255
36	0.00	1,857,996	$0.2600	4.0%	$483,166.78	84,328	398,839
37	0.00	1,857,996	$0.2704	4.0%	$502,493.45	84,328	418,165
38	0.00	1,857,996	$0.2813	4.0%	$522,593.19	84,328	438,265
39	0.00	1,857,996	$0.2925	4.0%	$543,496.91	84,328	459,169
40	0.00	1,857,996	$0.3042	4.0%	$565,236.79	84,328	480,909
						2,242,161	**7,931,587**

Assumptions: 4.5% interest rate for 5 yrs. And 5.5 % for 15 yrs.
BIA 20 yr.
Loan
Hydroelectric equipment and civil works @ $1,500 kW

G. Environmental Assessment

The project is based primarily on using water that is already being diverted for irrigation purposes; therefore there are no additional streambed impacts during the irrigation season. The diversion of water during the non-irrigation season will impact the stretch of the Rio Lucero that runs parallel to the Indian Ditch. The tail water from the turbine will return to the Rio Lucero below the Indian Ditch. It may be necessary to divert a smaller percentage during the winter months in order to maintain adequate water to the biotic community along that stretch of the Rio Lucero. The pipe replacing the Indian Ditch is proposed as part of the irrigation system rehabilitation so there would be no incremental impacts from using a higher-pressure pipe for hydroelectric purposes.

The electric line to deliver the power to the village area and the mini-grid in the village area would be buried as required by Taos Pueblo code. The buried power line would follow Rio Lucero road and not require any cross-country right-of-ways. The operation of the turbine has little impact, as there are no emissions and only a low level of sound.

H. Operation and Maintenance Training

The operation of the hydroelectric facility would most likely be through Taos Pueblo Utilities. Existing members of the staff can be trained in routine maintenance and operation functions. More technical maintenance can be done by local electricians or mechanics or trained personnel supplied by the technology vendors. Ideally, an employee or employees of Taos Pueblo Utilities would undergo a training course by the vendor in maintenance and operations. The day-to-day functioning of the turbine is by computerized controls and does not require a full-time operator.

I. Implementation Strategy

1. The project would first need to have the approval of the tribal council to begin more advanced planning. An in-depth presentation of the preliminary work accomplished by the present feasibility study would be necessary for an informed discussion and decision to occur. This would include a commitment of planning costs to complete the next level of feasibility study, which would cost on the order of $10,000 to $15,000. If these funds are not available then a plan to secure grant funding should be pursued. The Tribal Energy Program (Golden, Colorado) the BIA and the Department of Interior Indian Resources and Development program (Washington D.C.) and the USDA (Albuquerque) can assist.

2. Upon approval a project manager would need to be appointed who has a solid background in energy project development, and is conversant with hydroelectricity. A team of tribal members that will work with the project manager, including a grant writer, should be appointed.

3. Upon securing predevelopment funding, the project will first need a more thorough assessment by a hydroelectric equipment company such as Canyon Hydro of Deming, Washington or North American Hydro based in Wisconsin. This would include a scoping visit to the site. This may cost on the order of $5,000. The company would then develop a quote for turbine, generator and electronic controls as well as engineering. (The vendors supply much of the engineering as part of the cost of the equipment. The vendor can also supply a reasonable expectation of operations and maintenance costs. Plans and schematics would also be supplied by these vendors for the balance of project civil works. Additional preliminary engineering work would be needed to develop a Request for Quotes to be sent to local vendors for work such as trenching, pipe installation, pipe costs, power line installation, turbine housing and afterbay construction. A company capable of permitting and licensing the project (there are several in Santa Fe and Albuquerque) would need to contacted for a quote. All of the above would be compiled into a more detailed and up-to-date estimate of costs for the project than is supplied in the present study. License application through the Federal Energy Regulatory Commission (FERC) would have to be initiated. Because the project is less than 5 MW, Taos Pueblo would be exempted from the more involved licensing procedure. To initiate this process a Notice of Intent would be filed with FERC.

4. The project manager and tribal decision makers would initiate discussions with potential export buyers such as Kit Carson Electric Cooperative to determine interest level as well as a range of possible purchase prices for the power. Potential funding sources would be contacted to secure interest rates for capital. Based on the estimate of costs, including contingencies, and the expected value of the electricity on the market and in avoided electricity purchases; a business consultant can develop pro formas that would characterize the financials of the project. These financials should include iterations of different levels of buy-downs from grants, interest rate subsidies, and export sale prices. This would then determine if the project is feasible

5. If the project is to be pursued then discussions with potential buyers of power should be taken to the level of negotiating a power purchase agreement. An attorney and consultant with a background in power purchase agreements will have to be retained. Funding for

engineering and licensing in addition to attorney fees will need to be secured. This can be part of total project funding. Only the permitting, licensing funds need to be spent. Once the license from FERC is in place further expenditures are then reasonable.

The hydroelectric turbine for the Indian Ditch pipeline can be negotiated and paid for through the water rights settlement. Alternative funding approaches would include low interest loans through the Indian Energy Resources Development department created by the Energy Policy Act of 2005, a Rural Utility Service loan in coordination with a power purchase agreement with Kit Carson Electric Cooperative, or through the BIA Loan Guaranty, Insurance and Interest Subsidy Program ($7.5 million cap for tribal owned business). In terms of the water settlement, the avoided cost of the irrigation system can be paid by settlement money and the incremental cost of the hydroelectric can be paid through a commercial loan with BIA loan guarantees.

6. Upon completion of pre-development planning then actual construction can begin after a Request for Quotes has been issued and contracts have been awarded. The services needed will be a contractor for EPC or engineering, procurement and construction. The EPC contractor will use local and regional sources for trenching, pipe supply and pipe installation. The engineering and the hydroelectric equipment will be supplied by manufacturers such as Canyon Hydro of Deming, Washington, or North American Hydro of Wisconsin. (Both of these companies supplied no-cost consulting for this study, and have excellent history in small hydro). Kit Carson Electric Cooperative would install the buried power line and interconnection to the Kit Carson grid. An electrical contractor conversant in renewable energy interconnections such as Paradise Power or Valverde Energy would install the micro-grid to the various tribal buildings and wells.

7. Upon completion of the installation, employees of Taos Pueblo Utilities will be trained in the operation and maintenance of the equipment by the hydroelectric equipment vendor. The project is commissioned for operations by the hydroelectric equipment supplier and Kit Carson Electric Cooperative.

8. This is a draft of a business plan. Upon decision to proceed with this project there will be the need at that time to secure quotes from vendors and on the basis of those quotes updated pro forma spreadsheets will need to be developed. This will be necessary in order to approach a commercial bank for a loan (if necessary) or for the basis of negotiations with the Federal government if water settlement funds are to be used.