8.0 Hydro

Hydroelectric power captures the kinetic energy of water as it moves from a high elevation to a lower elevation by passing it through a turbine. The amount of kinetic energy captured by a turbine is dependent on the head (distance the water is falling) and the flow rate of the water.

Hydropower is typically associated with capturing energy in natural watercourses as they flow towards the sea. However, other creative schemes, such as pumped storage using saltwater and capturing groundwater have been proposed, even on Kauai. One scheme proposed in the 1940's considered diverting water trapped in Kauai's basalts for hydropower generation.[70]

Often, water is raised to a higher potential energy by blocking its natural flow with a dam. Projects that store large amounts of water behind a dam regulate the release of the water through turbines over time and generate electricity regardless of the season. These facilities are generally base loaded. Pumped storage hydro plants pump water from a lower reservoir to a reservoir at a higher elevation where it is stored for release during peak electrical demand periods.

Another method of capturing the kinetic energy is to divert the water out of the natural or artificial waterway, through a penstock and back to the waterway. Such "run-of-river" or "run-of-ditch" applications allow for hydroelectric generation without the impact of damming the waterway. Often resources of adjacent drainage basins are diverted to increase the total flow, and thus power production.

The existing worldwide installed capacity for hydroelectric power is by far the largest source of renewable energy at 740,000 MW. However, for reasons discussed later in this section, many environmental groups object to the broad definition of hydroelectric resources as renewable. Numerous classification systems for hydro have developed in an attempt to distinguish "renewable" projects. Generally this distinction is based on size, although "low-impact," low-head, and run-of-river plants are also often labeled renewable. Size classifications for smaller hydro systems include:

- Micro - up to 100 kW
- Mini - 100 kW to 1.5 MW
- Small - 1.5 MW to 30 MW

Because of the limited geographic extent and population base on Kauai, all existing and proposed hydroelectric projects fall into these three categories.

[70] Orion Engineering, Inc., Wainiha Hydroelectric Project Environmental Impact Statement, Volume II, prepared for McBryde Sugar Company, August 1983, p. 127.

8.1 Basis for Assessment

Hydropower potential for Kauai was assessed based on information available in numerous public reports provided by KIUC, other individuals, or available on the internet. These reports are referenced throughout this section. Current information on the status of potential projects and attitudes toward hydropower development were based on conversations with individuals associated with hydropower development on the island.

Studies completed by the Department of Energy have evaluated hydropower potential in Hawaii on a regional basis based on general rainfall and topography.[71] However, even screening level studies have to be based on site specific input because of the complex interrelationship between rainfall, topography, geology and water use. Because of this, more than other types of renewable energy sources, hydro project costs and feasibility are very site specific. The assessment of hydro potential was therefore based largely on published reports by the federal government, state government, and private developers looking at specific project sites.

In order to supplement information found in the reports with current activity and perceptions, telephone contacts were initiated with the following individuals:

- Dennis Watt, U.S. Bureau of Reclamation, Boulder City, NV
- Laurie Ho, Natural Resource Conservation Service, Lihue, Kauai
- Mina Morita, District 12 State Representative, Honolulu, Oahu
- Maria Tome, Alternative Energy Engineer, State of Hawaii, DBEDT
- David Rezachek, Consultant/former DBEDT
- Mike Kido, University of Hawaii Center for Conservation Research & Training
- Jerry Ornellas, President, East Kauai Water Users Cooperative
- Jeff Deren and Joe McCawley, KIUC, Lihue, Kauai
- Charlie Okomoto, Finance Director, Gay & Robinson, Kaumakani, Kauai
- Owen Moe, Engineer, Gay & Robinson, Kaumakani, Kauai
- Randy Hee, former McBryde Sugar engineer, Kekaha, Kauai
- John Wehrheim, Pacific Hydro, Kauai
- Brent Smith, Northwest Power (Symbiotics), Rigby, ID
- Kearon Bennett, Ottawa Engineering Limited, Ottawa, Ontario, Canada

Maria Tome, Mike Kido, Jerry Ornellas, John Wehrheim and Kearon Bennett were unavailable for comment.

[71] U.S. Department of Energy Report DOE/ID-11111, "Water Energy Resources of the United States with Emphasis on Low-Head/Low Power Resources," April 2004.

8.2 Assessment of Contributing Resource

The flow of water in a river basin is largely a function of size, topography and climate. In many respects, Hawaii, and Kauai in particular, is an ideal location for development of hydropower resources because it is endowed with hydropower's two main needs: precipitation and elevation drop. Due to the island's small size, tributary drainage areas are small, which is not typically ideal for hydropower. Nevertheless, on Kauai, basins are often productive hydrologically due to their topography and rainfall.

8.2.1 Topography

The conical topographical shapes produced by the volcanic origins of Hawaii result in relatively steep gradients from the volcano crater to the ocean. In general, this is a benefit for hydropower. Hydropower is most economical when there are drops in elevation of hundreds of feet in short distances since penstock and access costs as well as hydraulic head losses are a function of distance. For run-of-river projects, often volcanic slopes do not have gradients steep enough to result in economical projects. Fortunately, Kauai has the advantage of being the oldest of the major Hawaiian Islands. The forces of erosion have over time created steeper canyons where high short drops in topography are available. The Waimea Canyon is one such location. Waterfalls abundant on Kauai provide another "natural" location to derive benefits from hydropower.

8.2.2 Rainfall

The summit of Mount Waialeale on Kauai is known as "the wettest spot on earth" because of its average annual precipitation over 400 inches. Waters flowing from the summit of this mile-high mountain produce 61 perennial streams and many more intermittent streams.[72] Rainfall along the coast drops to as low as 20 inches per year.

As in other tropical climates, rainfall on Hawaii can vary greatly from year to year. In high rainfall areas, monthly averages can vary as much as 200 to 300 percent between years.[73] Monthly variation in rainfall can be seen for select stations in Figure 8-2 below. Mount Waialeale is the wettest of the rainfall stations and Makaweli on the southwest coast is the driest. The two Wainiha stations are representative of rainfall in areas of existing and proposed hydropower plants. It can be seen that dryer summer months (May through September) give way to wetter winter months (October through April), but that unlike some other parts of the United States, precipitation is generally year-round. This is useful for hydropower from the standpoint of power generation.

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[72] U.S. Fish and Wildlife Services, "Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Newcomb's Snail; Final Rule, 50 CFR, Part 17, August 20, 2002.

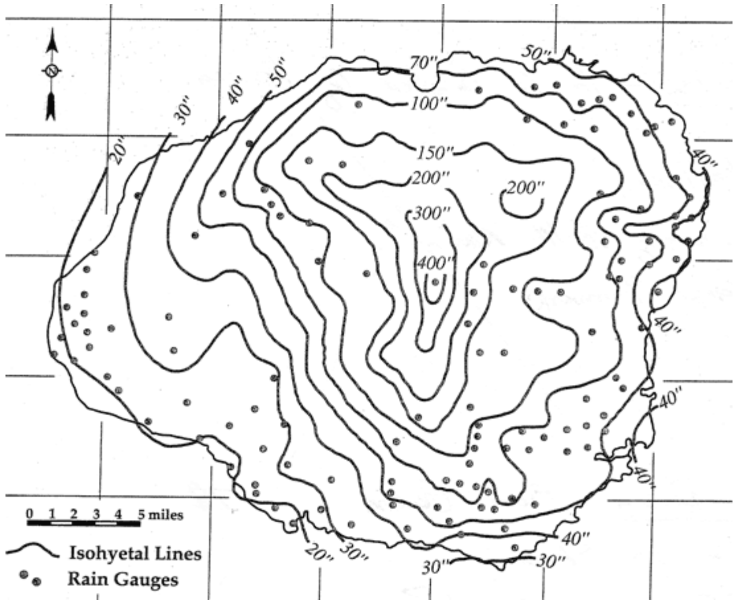

Figure 8-1. Kauai Average Annual Rainfall Map (source: http://www.balihai.com/islandinfo/kauai_maps.html).

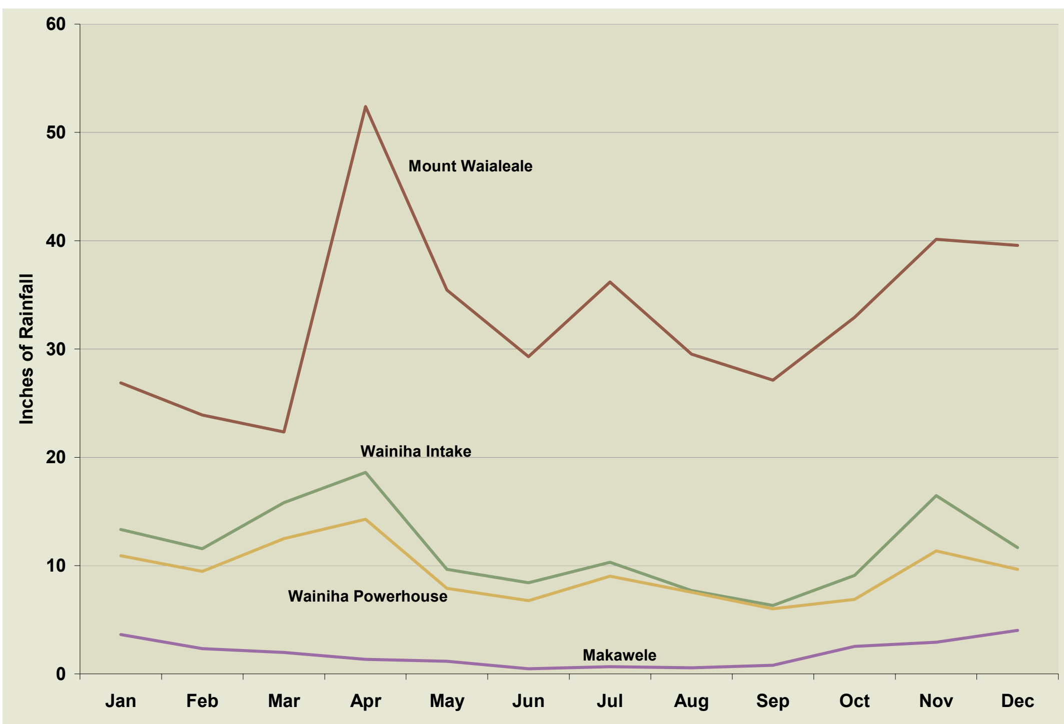

Figure 8-2. Monthly Precipitation at Select Stations in Kauai, Average 1970-2002 (Source: University of Hawaii).

[73] National Oceanic and Atmospheric Administration, National Climactic Data Center, "Climate of Hawaii," http://www.wrcc.dri.edu/narratives/HAWAII.htm

Discrete winter storms resulting in high stream flows provide much of the total precipitation records at these rain gages. Nevertheless light showers are also quite common throughout Hawaii.[74] Rainfall in Hawaii tends to fall more at night or early morning. This diurnal variation is more pronounced during the summer than in the winter.[75] Overall rainfall patterns and geography are favorable to hydropower in Kauai, but yearly, seasonal, and daily variations will impact the consistency of power production.

Stream gaging stations is available throughout Kauai. Many of these are associated with the plantation irrigation systems where hydropower projects are likely to occur. Because the translation of existing stream flows to site specific flows requires significant effort, especially in view of the complex irrigation systems in some areas, individual stream gage data was not reviewed for this report. Flow data was based on previous studies noted herein.

An example of stream flow is shown below in Figure 8-3. The gaging station is located between the diversion and powerhouse of the proposed upper Wainiha project. As this is an uncontrolled stream, the flow curve reflects the precipitation curves for the existing Wainiha Diversion and Powerhouse in Figure 8-2.

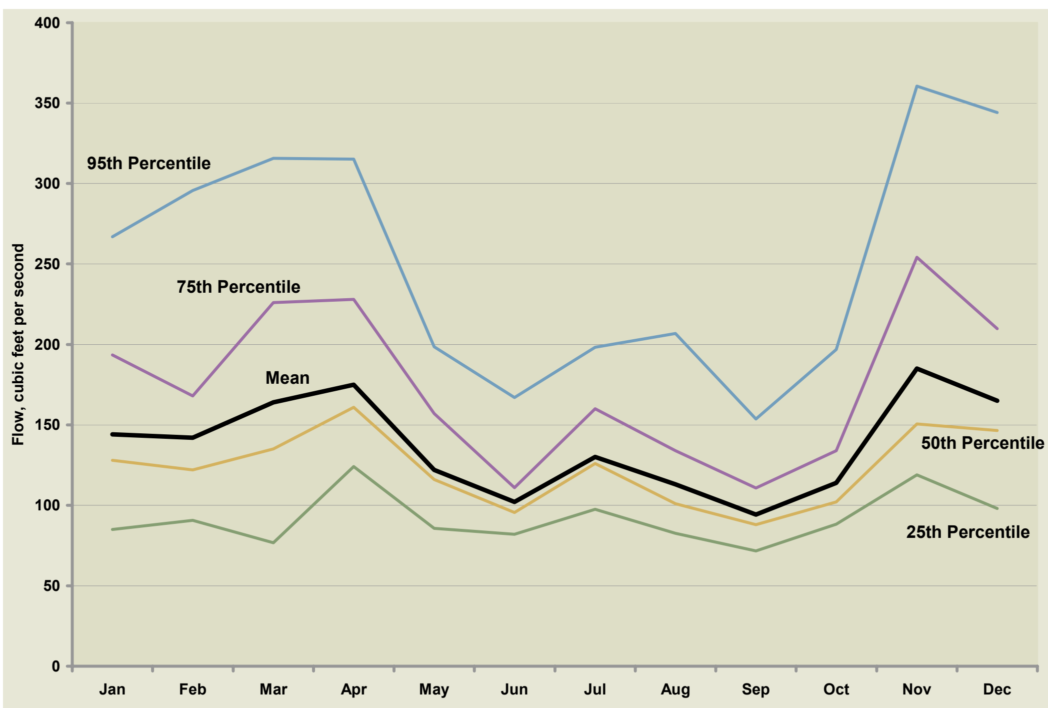

Figure 8-3. Monthly Stream Flows on Wainiha Stream (Source: USGS).

[74] National Oceanic and Atmospheric Administration, National Climactic Data Center, "Climate of Hawaii," http://www.wrcc.dri.edu/narratives/HAWAII.htm
[75] ibid

8.2.3 Use of Water for Hydropower

Hydropower is a fully commercial technology that already makes a significant contribution to the electric supply on Kauai. The early economic development of Kauai progressed hand-in-hand with hydropower development as sugar plantations sought power to run their mills. The demise of the sugar industry in the last half of the 20th century has meant that many of the water and hydropower resources have not been economical to maintain from an agricultural standpoint. In spite of this, the seven powerhouses still account for 8.8 MW of the island's 135.8 MW of generation, or 6.5 percent.[76]

The demise of plantation agriculture presents a unique opportunity for hydropower on Kauai. The value of water can be converted from agriculture to power generation. Many existing facilities can be renovated and upgraded to make hydropower cost-competitive. Most of the existing and proposed projects fall into this category of utilizing existing irrigation resources. In cases where agriculture is still an important use for the water, water delivery systems can be developed with the flexibility to provide water for irrigation as needed while surpluses generate electricity.

The waters of the State are controlled by the State of Hawaii. Currently water use leases administered by the Department of Land and Natural Resource are for one year and are revocable.[77] During the last 20 years, no new leases have been issued for water in irrigation systems.[78] Longer-term leases are likely to be required if development of hydropower is to be financially feasible.

8.3 Project Option Screening

A total of 41 new and 8 existing projects were identified from previous reports and telephone interviews. Projects were grouped into four major regions dominated by historic agricultural use: north, east, south and southwest. A complete list of these projects is found in Appendix A. A 1978 U.S. Army Corps of Engineers (Corps) study identified four potential new projects on Kauai.[79] A 1981 Corps Study identified seven different projects including five new and two upgrade projects.[80] These Corps projects

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[76] U.S. Bureau of Reclamation, Lower Colorado Region, "Preliminary Assessment of Small Hydropower Potential on East Kauai Water Users Cooperative Lands and Other Kauai Agricultural Water Delivery Systems," prepared by Ottawa Engineering Ltd., November 2004, p. 33.

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[77] ibid, p.14.

[78] ibid, p.14.

[79] U.S. Army Corps of Engineers, Honolulu District, Summary Report for Hydroelectric Power, October 1978.

[80] U.S. Army Corps of Engineers, National Hydropower Resources Study, Regional Assessment: Alaska and Hawaii, Volume XXIII, September 1981.

were summarized by the State of Hawaii in a 1981 report.[81] Later, the US Department of Energy began a database of potential hydropower projects that currently includes eight new projects, some which were earlier identified by the Corps.[82] In fact, several of the proposed projects were variations of one another based on differing diversion points often within existing complex irrigation schemes such as in the Wailua and Kokee areas.

Of these 49 projects, a total of five projects (three new and two upgrade) were selected based on the frequency of mention, freedom from prohibitive environmental issues, and relatively high energy production based on cost. One of the projects (Kokee) has two powerhouses, resulting in six total sites. All of these projects are run-of-river or run-of-ditch, although some involve the use of existing reservoirs currently not generating hydropower. The location of these projects is shown in Figure 8-4. The five selected projects are listed in Table 8-1.

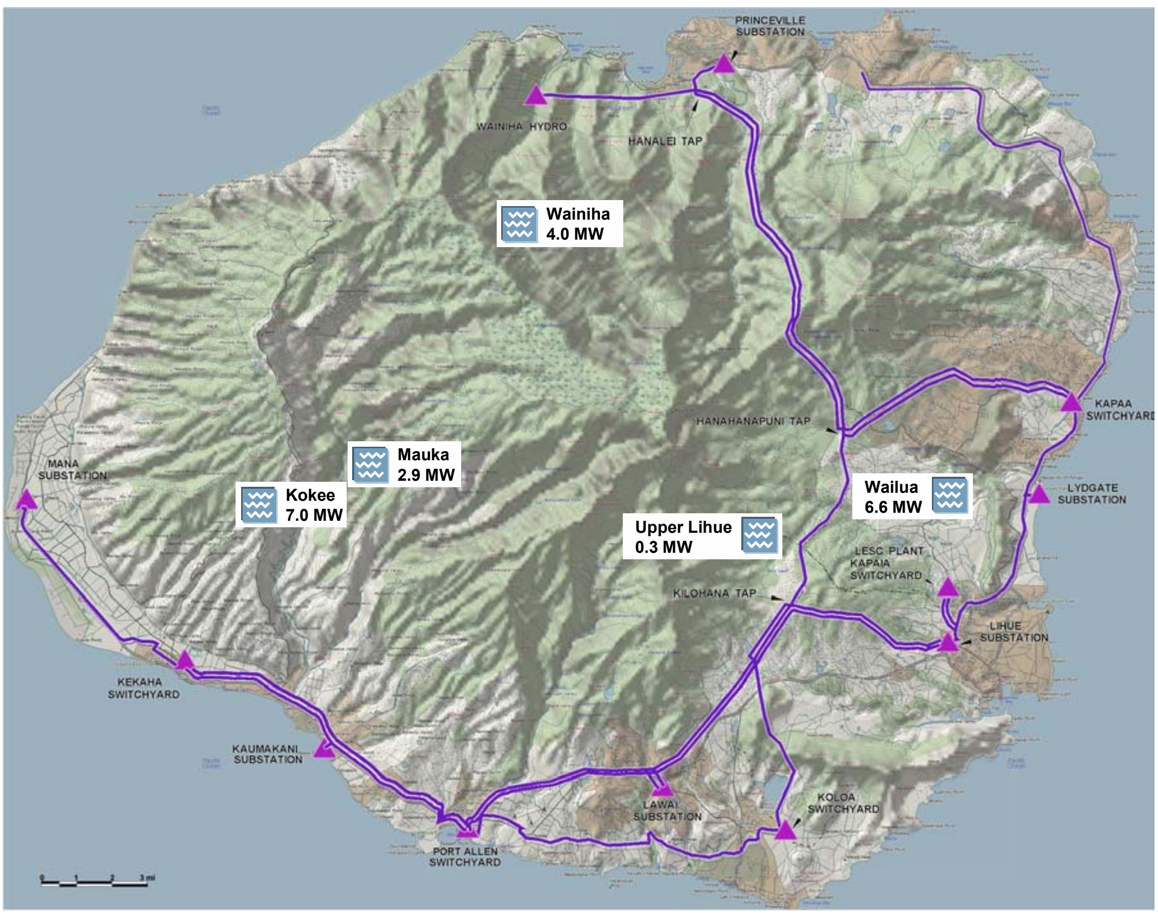

Figure 8-4. Map of Selected Hydropower Projects.

[81] W.A. Hirai & Associates, Hydroelectric Power in Hawaii: A Reconnaissance Survey, prepared for State Department of Planning and Economic Development, February 1981.
[82] U.S. Department of Energy, Idaho National Engineering and Environmental Laboratory, Hydropower Resource Economics Database, Public Version, April 28, 2003.

Table 8-1. Selected Hydro Projects.								
No.	Project Name	Status	Type	Static Head (ft)	Design Flow (cfs)	Plant Size (kW)		
						Exist.	Prop.	Total
1	Wainiha	new	run-of-river	433	139	0	4,000	4,000
2	Upper Lihue	upgrade	run-of-river	247	32	500	300	800
3	Wailua	new	run-of-river	262	150	0	6,600	6,600
4	Waimea Mauka	upgrade	run-of-river	265	55	1,000	2,900	3,900
5A	Puu Lua-Kitao	new	run-of-ditch	1,145	40	0	2,970	2,970
5B	Kitano-Waimea	new	run-of-ditch	2,093	30	0	4,078	4,078

8.4 Project Technical Descriptions

This section provides descriptions of the five projects.

8.4.1 Wainiha

The Wainiha project is on north side of the island upstream from an existing 3.6 MW powerhouse developed by the McBryde Sugar Company in 1906. The existing Wainiha powerplant is shown in Figure 8-5.

Figure 8-5. Existing Wainiha Hydropower Plant.

In the early 1980's McBryde commissioned a private study to optimize the hydropower potential based on balancing increased head moving upstream with decreased flows and increased access and penstock costs. The project was advanced to the point of completing the Environmental Impact Statement (EIS).[83] All of the necessary permits, including FERC and the Corps 404 were applied for and some state permits had already been issued. No salient biological or cultural resources created significant concern. Nevertheless, for economic reasons, McBryde Sugar abandoned the project in favor of other endeavors. Relatively low oil prices apparently made the project unattractive.

Unlike most new hydropower projects, Wainiha has not faced as much opposition partly because the stream and area have been disturbed for almost a century. The EIS points out that wildlife has flourished with the existing project. Since the new project is very similar, the same is expected. The project also has the advantage of being located in the rural north, far from the more urbanized eastern and southern portions of the island. Development of electricity in the area could improve the reliability of electrical service in an area distant from other power sources.

Access to this project is believed to be a significant factor since the highway leading to the north shore has 8- to 12-ton weight limits. Larger equipment may be transported by barge to the Wainiha Beach. The existing 4.3-mile access road from the highway to the existing powerhouse will have to be improved and well as construction of a new 2.1-mile access road.

Two other project influences are worth noting. One is that the land where the project is to be located is now owned by Kauai Coffee whose interest in the project, like those many agribusinesses, is likely to be primarily economical. Second, lands downstream from the project are cultivated in taro. Any changes occasioned by the project will need to address the needs of this traditional practice.

8.4.2 Upper Lihue

The Upper Lihue (Upper Waiahi) power plant was constructed in 1931 by the Lihue Plantation, which later sold power to Kauai Electric / KIUC as irrigation power needs declined. When Lihue Plantation ceased operation, KIUC received ownership of the plant. Due to a lack of funding for maintenance, the capacity of the conveyance system leading to the Upper Lihue power plant has been reduced from its original capacity of 25 to 30 million gallons per day (MGD) to approximately 17 MGD. The existing 36-inch penstock is believed to have been originally designed for 20 MGD, but appears to have been capable of carrying even higher flows judging by its relatively large diameter. A second footing and tailrace at the powerplant is also evidence that additional

[83] Orion Engineering, Inc., Wainiha Hydroelectric Project Environmental Impact Statement, Volume II, prepared for McBryde Sugar Company, August 1983.

capacity was incorporated into the original design. Nevertheless the capacity of the penstock has also eroded over time due to corrosion on the inside of the steel pipe.

Recommendations for rehabilitation of the conveyance canal and power plant have been made since at least the early 1980's. The history of these recommendations are summarized in a February 2003 study by Pacific Hydroelectric Company.[84] The most recently proposed project would upgrade the plant from 500 kW to 800 kW by replacing the Iliiliula Intake trashrack, restoring the debilitated Iliiliula Flume, increasing the penstock diameter from 36 to 42 inches, and adding a 300 kW Pelton turbine at the existing powerhouse. Additional work to restore other segments of the conveyance system and increase its capacity to 32 MGD were assumed to take place in advance of this project. This additional work would include improving and restoring abandoned stream gages and adding a sluice gate to the Waioki Intake. Cost information for this project is summarized in a May 2003 Pacific Hydroelectric report.[85]

Figure 8-6. Lower Lihue Plant 800 kW Turbine.

8.4.3 Wailua

The Wailua River has been the subject of numerous studies in the last 25 years because of its productive watershed. In fact, Wailua is the only Kauai hydro project that is currently listed in the State's Renewable Energy Resource Assessment and

[84] Pacific Hydropower Company, Upper Waiahi Hydro: Preliminary Source Investigation and Feasibility Study for a Second Turbine, prepared for Kauai Island Utility Cooperative, February 2003.
[85] Pacific Hydropower Company, Waiahi Upgrade Budgetary Cost Estimate, prepared for Kauai Island Utility Cooperative, May 2003.

Development Program.[86] The proposed 6.6 MW scheme diverts water above Wailua Falls to a downstream power plant. It has the advantage of being located in already developed areas, ensuring ready access and avoiding disturbance of pristine habitat.

In the 1980's Island Power pursued a project and completed an Environmental Impact Statement. Reportedly, development was halted not so much from overwhelming opposition to the project, but poor presentation of the project details showing knowledge of local conditions.

In 2001, Northwest Power, a hydropower developer operating under the name Symbiotics LLC, filed a Preliminary Permit Application with the Federal Energy Regulatory Commission (FERC) on the Wailua project.[87] This application was one of 250 filed by Northwest Power with FERC, but the only one in Hawaii. Concerned responses from individuals, local groups and state and federal agencies were filed shortly thereafter, primarily directed at environmental concerns. In 2004, under pressure from FERC to demonstrate progress on this application, Northwest Power, operating now under the name Pacific Energy Resources, filed a new Preliminary Permit Application for the same project. The application was accepted for filing under Project No. 12534 on December 17, 2004. Completion of the permitting process is expected to take three to five years.[88] To our knowledge, this makes Wailua the only project currently under active pursuit in Kauai.

The project addresses the primary environmental concern of diverting water above the prominent Wailua Falls by maintaining minimum instream flows of 15 cubic feet per second. Wailua Falls is widely known because of its feature in the 1978-1984 television series, *Fantasy Island.* Project components are planned to be invisible from the Wailua Falls overlook, a popular tourist destination. Portions of the project fall within Wailua River State Park.

Because the Wailua project is active, it presents a glimpse of current attitudes towards hydropower development in Kauai. Many on Kauai are in favor of renewable energy including hydropower. After a visit by the U.S. Bureau of Reclamation to a potential hydropower site near Wailua Reservoir near the Himalayan Academy, this Hindu monastery posted pictures of the visit with the comment that "a local renewable source will be a small contribution to the new world order of self-sustaining cultures."[89] Some however, will apparently be opposed to this project regardless of how development is approached. The Kauai Development Digest urges petitions to FERC against the

[86] State of Hawaii, Department of Business, Economic Development and Tourism, Renewable Energy Resource Assessment and Development Program, 1995, updated in 2000 and 2004.
[87] Symbiotics, LLC, Lower Wailua Hydroelectric Project, FERC No. 12025, 4 pp., no data.
[88] TenBruggencate, Jan, "Proposal for dam rekindled on Kaua'i," Honolulu Advertiser, January 11, 2005,

Wailua project because it would "reduce the flow of Wailua Falls and might endanger native fishes."[90] Like any significant development, hydropower projects are likely to be opposed by at least some.

Figure 8-7. Wailua Falls.

8.4.4 Waimea Mauka

The Waimea Mauka plant in the southwestern portion of the island could receive an upgrade from 1.0 MW to 3.9 MW according to the 1981 Corp study.[91] It was listed as a project of "medium potential". The only Kauai project with "high" potential, the Kaumakani hydropower plant, has already been upgraded. No other details were available on this concept. It is likely that additional capacity is based on utilizing the existing Waiahulu Intake and Waimea Mauka powerplant and converting portions of the

[89] Himalayan Academy website, Daily Chronicle for August 25, 2004, http://www.himalayanacademy.com/taka/past/2004/August/August_25_2004/
[90] Environment Hawaii, Kauai Development Digest, no date, http://www.environment-hawaii.org/ddkauai.htm.
[91] U.S. Army Corps of Engineers, National Hydropower Resources Study, Regional Assessment: Alaska and Hawaii, Volume XXIII, September 1981.

upstream Kekaha Ditch to penstock to generate additional head. A photo of the generator at the existing power plant is shown in Figure 8-11.

Along with the Kokee project below, the lands draining this project are under the influence of the State Department of Agriculture under the auspices of the Agribusiness Development Corporation (ADC). ADC is also the current project owner. The ADC was formed in 1994 to facilitate and provide direction for the transition of Hawaii's agriculture industry from a dominance of sugar and pineapple to one composed of a diversity of different crops. One of its main objectives is to facilitate in the orderly transition of existing agribusiness resources of land, water and infrastructure as they become available.[92] Another influence on this and the Kokee project may come from one of the last remaining plantation holders, Gay & Robinson, who control 51,000 acres in the area from their headquarters in Makaweli. Gay & Robinson is interested in renewable energy including hydropower to the extent that it creates a positive financial opportunity.

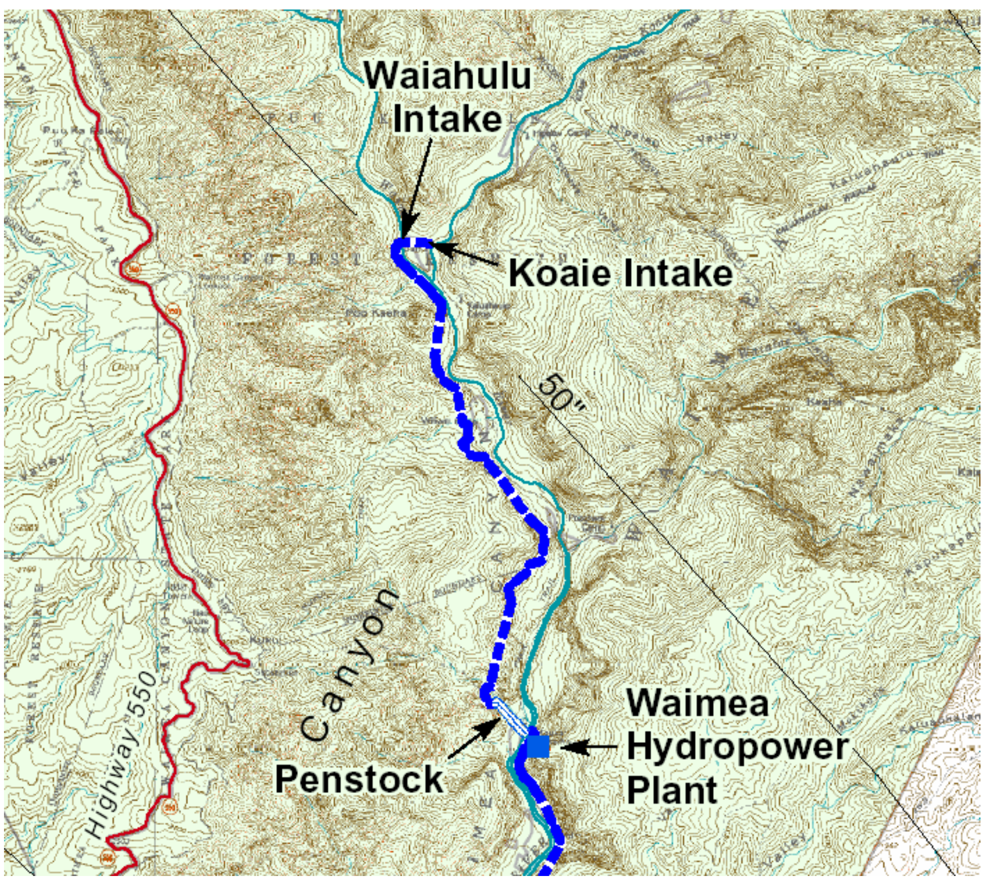

Figure 8-8. Waimea Mauka Hydropower Plant Vicinity (source: Hawaii DOA).

[92] http://www.hawaiiag.org/hdoa/adc.htm

8.4.5 Kokee

A project which utilizes the developed irrigation systems on the west bank of Waimea Canyon has been envisioned for many decades. A 1964 plan for a large 10 MW storage project never materialized. Later variations in the project included a series of three hydropower plants using existing reservoirs and ditch alignment.[93] The third plant was located on Mana Ridge and required a new easement for the conveyance. This new easement could result in environmental obstacles for realization.

The two-step system recently outlined by the Bureau of Reclamation relies on historical flows along existing ditches and rights-of-way.[94] A 2.97 MW powerhouse at Kitano reservoir would be fed from Puu Lua Reservoir. A second 4.08 MW powerhouse along the Waimea River would take advantage of the steep west canyon wall of this scenic area. The total plant capacity is 7.0 MW exclusive of two small irrigation return turbines which would recapture unused irrigation water. This scheme was selected for consideration because it utilizes existing easements and allows for flexible irrigation flows.

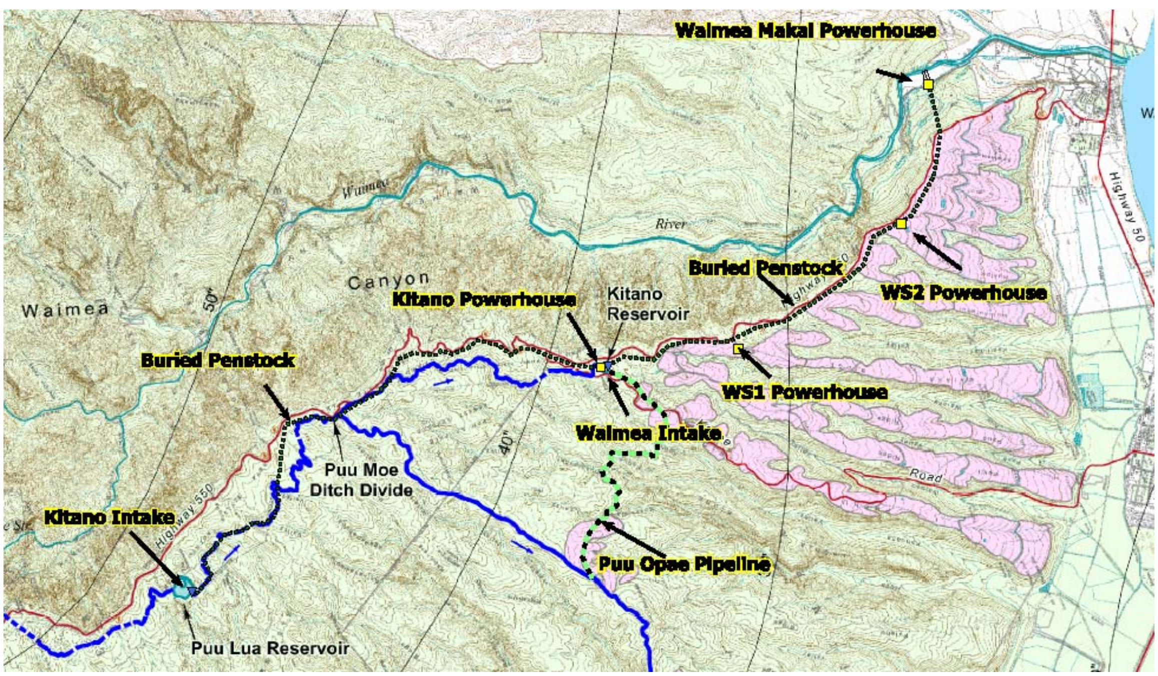

Figure 8-9. Kokee Project Vicinity (source: U.S.B.R. 2004).

93 State of Hawaii Department of Land and Natural Resources, Puu Lua-Kokee Hydropower Project: Environmental Impact Statement (Report R70), April 1984.

94 U.S. Bureau of Reclamation, Lower Colorado Region, "Preliminary Assessment of Small Hydropower Potential on East Kauai Water Users Cooperative Lands and Other Kauai Agricultural Water Delivery Systems," prepared by Ottawa Engineering Ltd., November 2004.

Two Hawaiian Home Lands are apparently located in the vicinity of the project area. Development of the project would thus require consultation.

Costs for the two plants were estimated by the Bureau using RETScreen, renewable energy estimation software developed by the Canadian Department of Natural Resources.

8.5 Power and Energy Production

8.5.1 Plant Performance

There are a variety of methods to estimate performance of proposed hydro projects. One useful method of estimating plant performance is to review generation records for the island's seven existing hydropower plants. However, because these plants were largely in private hands until recently, these records may be difficult to obtain. Power generation records for the existing seven hydropower facilities were not available for review for this study.

A second method of estimating performance is to convert inflow hydrographs into generation based on assumed hydraulic and mechanical efficiencies. Hydrographs can be turned into flow duration curves which plot flow on one axis and frequency of exceedence on the other axis. The flow duration curves for Wainiha and Upper Lihue are available from reports, but not for the other three projects. Nevertheless, the basic data used to develop the flow duration curves was not included in these reports.

The Wailua, Upper Lihue and Kokee plants involve a complex series of diversions, many of which have gaging stations that have been abandoned. Only the Wainiha and Waimea Mauka projects have hydrographs that can be scaled to develop a meaningful powerhouse flow duration curve. Unfortunately, the exact configuration of the proposed Waimea Mauka plant is unknown. For the Wainiha plant, the flow duration curve was developed based stream flow data from 1952 through 2003 (Figure 8-10). An adjustment was not made from the gaging station to the proposed diversion site upstream, but this is only expected to result in a reduction of flows on the order of 10 percent.

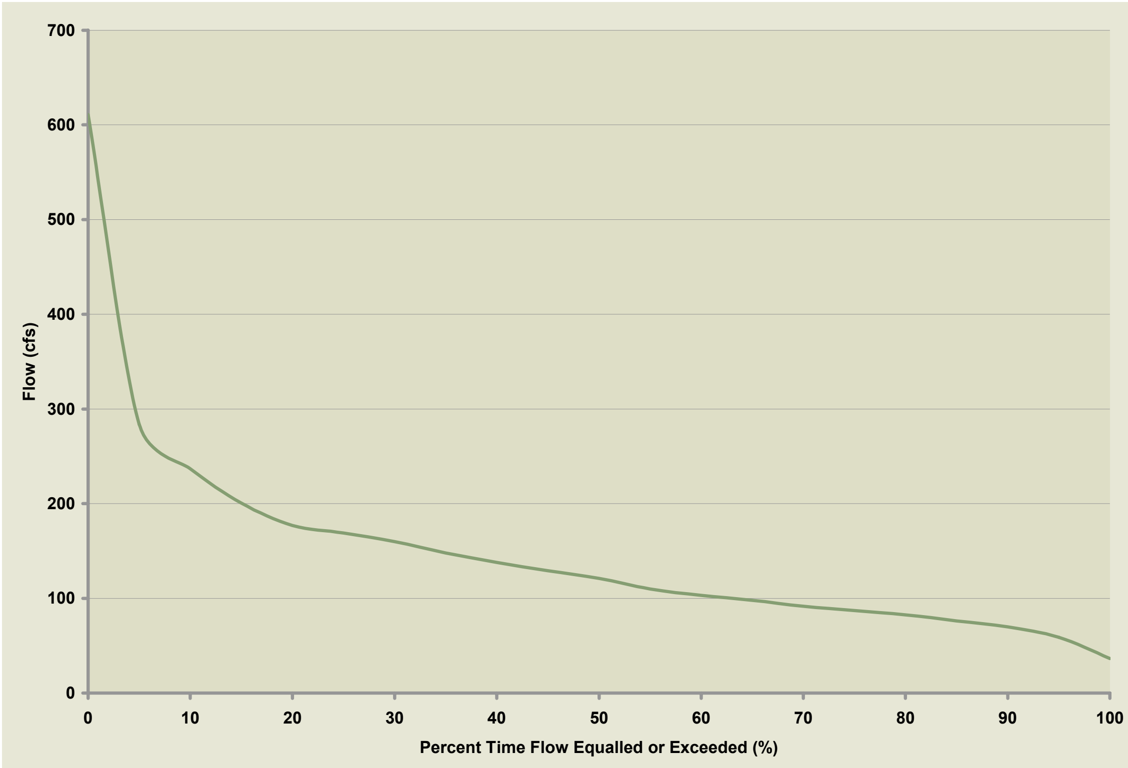

Figure 8-10. Wainiha River Flow Duration Curve, 1952-2003 (Source: USGS).

The additional data since the 1983 EIS does not change the basic shape of the curve, but probably lowers it slightly due to several dry years in the last twenty years.

A RETScreen analysis was used to roughly evaluate the sizing and estimated energy production for the proposed Wainiha Powerplant. A net head of 357 feet was used from the EIS. The calculated turbine and assumed generator efficiencies were 90 percent and 98 percent, respectively. A two-week annual downtime for maintenance was also assumed.

The plant capacity was calculated as 3.9 MW, which matches the 4.0 MW turbine capacity proposed. The annual generation was calculated as 16.9 GWh, which is about 23 percent less than the EIS figure of 22 GWh. The capacity factor calculates at 89 percent, which is in the upper range of the typical 40 percent to 95 percent for small hydroelectric projects. Further studies as recommended in Section 8.8 would be needed to verify these figures.

8.5.2 Operating Profile

Hydro is an intermittent resource and output will vary with rainfall as described previously.

8.6 Cost of Energy

This section presents information to calculate the generation cost of hydro projects including capital cost, O&M cost, and a discussion of applicable incentives. The capital and O&M cost estimates for each of the six projects is shown in Table 8-2. A description of how these values were determined or calculated is below.

Table 8-2. Capital and O&M Costs (2005$) for Selected Hydro Projects.

No.	Project Name	Incremental kW	Incremental GWh/yr	Capital Costs		O&M Costs	
				$M	$/kW	$k/yr	$/kW-yr
1	Wainiha	4,000	22.5	18.0	4,496	270	67.46
2	Upper Lihue	300	1.8	2.2	7,248	30.5	101.82
3	Wailua	6,600	16.4	13.5	2,044	205	31.09
4	Waimea Mauka	2,900	3.9	3.5	1,213	80	27.65
5A	Puu Lua-Kitano	2,970	15.8	17.6	5,933	266	89.64
5B	Kitano-Waimea	4,078	17.1	16.1	3,955	251	61.62

8.6.1 Capital Costs

A nationwide database of hydropower construction cost information per kW of capacity is available from the DOE.[95] In 2003, the nationwide average to develop a hydropower project ranged from about $500-6,000/kW, with a median about $2,700/kW for an undeveloped site, and $700/kW for upgrade projects at sites with existing generation. As would be expected, specific costs decrease with plant size and previous development of the site. Most of the selected projects fit within this range.

Like wind and solar, capital costs for hydropower projects make up most of the overall costs since the "fuel" is "free" once the required infrastructure is in place. For hydropower projects, much of the cost is often off-site from the power plant in the diversion structures, penstock, and their associated access roads. The variability in project site requirements leads to broad ranges of potential costs. For this reason, it is difficult to develop generic estimates of project costs without detailed site studies, and past detailed estimates, despite their age, are preferred.

[95] Idaho National Engineering and Environmental Laboratory, "Estimation of Economic Parameters of U.S. Hydropower Resources," June 2003.

The Wailua project, and to a lesser extent the Upper Lihue project, are the only projects with line-item construction cost estimates that closely reflect the selected project. Total project cost is all that was available for the Wainiha, Waimea Mauka, and Kokee projects. It is assumed, but could not be verified, that all these lumped costs include engineering and construction administration as well as any required transmission upgrades. Costs were updated from the time of the initial project reports to November 2004 based on the Engineering News Record Construction Cost Index.[96]

8.6.2 Operating and Maintenance (O&M) Costs

Project O&M costs are estimated based on percent of construction cost and staff allocation. The Corps has used 0.5 percent of the construction cost for annual O&M.[97] However, since these plants are small, and two projects are upgrades, this cost was assumed to be 1 percent. O&M costs are expected to be higher for upgrade plants because, though some of the equipment would be new, the diversion and conveyance structures may still require a greater level of maintenance than a new project. One tenth of one percent (0.1 percent) is assumed to be contributable to insurance.

The O&M cost assumes automated power plants with remote monitoring via radio telemetry. Although full-time, on-site personnel are not typically required at these plants, staff will be needed for monitoring, routine site visits, troubleshooting, and annual maintenance. It is assumed that one full staff would be assigned for each of the three new projects (Wainiha, Wailua and Kokee), and that one-half staff unit be added for Waimea Mauka. No additional effort was believed to be needed for the Upper Lihue plant based on the small increase in capacity. Each staff unit was estimated at $90,000 per year including salary and benefits. This addition should give a conservative estimate for annual O&M costs.

[96] http://enr.construction.com/features/coneco/subs/constIndexHist.asp.
[97] U.S. Army Corps of Engineers, Honolulu District, Summary Report for Hydroelectric Power, October 1978, p. C-9.

Figure 8-11. Waimea Mauka Powerhouse Generator Maintenance (Source: Hawaii Business Magazine, Nov. 2003).

8.6.3 Applicable Incentives

In 2002, State Representative Mina Morita submitted a bill to provide a tax credit of 20 percent for hydroelectric systems erected and placed in service between 2003 and 2010. This bill never passed. The bill which did pass included tax credits only for solar and wind energy. This exclusion, however, apparently was due to State budget limitations rather than a preference for a particular renewable energy technology.[98]

There are several federal incentives available for the development of hydroelectric generation facilities. The federal production tax credit provides a $9/MWh incentive for five years following the initial commercial operation date of the facility, however the facility must be owned by a taxable entity to claim this credit. The hydroelectric facility must also be located in an irrigation system and not use any new dams or impoundments. The incentive would be available for the Upper Lihue, Waimea Mauka, Puu Lua-Kitano, and Kitano-Waimea projects. This incentive is included in the life-cycle cost analysis for the developer owned scenario. Various federal grants and low interest loan programs may also be applicable to these projects; however, the exact impact of these programs is uncertain and not quantified at this time. Therefore, no incentives are assumed in the life-cycle cost analysis for the KIUC ownership scenario.

8.6.4 Life-cycle Economics

The life-cycle cost of providing power from each of the proposed hydroelectric projects was evaluated by calculating the levelized cost. The hydro project performance

[98] Personal electronic mail correspondence from Rep. Mina Morita, November 16, 2004.

and economic assumptions as well as the results of the life-cycle cost analysis are presented in Table 8-3. A discussion of the modeling approach and detailed financial assumptions are provided in Section 5. Figure 8-12 shows an example life-cycle cost calculation for the Waimea Mauka project.

Table 8-3. Hydro Life-Cycle Economic Assumptions ($2005).

	Unit	Wainiha	Upper Lihue	Wailua	Waimea Mauka	Puu Lua-Kitano	Kitano-Waimea
Capacity	MW	4	0.3	6.6	2.9	2.97	4.078
Capital Cost	$/kW	4,496	7,248	2,044	1,213	5,933	3,955
First Year Fixed O&M	$/kW-yr	67.5	101.8	31.1	27.7	89.6	61.6
First Year Variable O&M	$/MWh	N/A	N/A	N/A	N/A	N/A	N/A
First Year Fuel Cost	$/MBtu	N/A	N/A	N/A	N/A	N/A	N/A
Net Plant Heat Rate	Btu/kWh	N/A	N/A	N/A	N/A	N/A	N/A
Capacity Factor	percent	64%	69%	28%	15%	61%	48%
KIUC Levelized Cost	2009$/ MWh	58.4	86.1	60.4	79.1	81.8	69.9
KIUC Premium	2009$/ MWh	(116.3)	(88.6)	(114.4)	(95.7)	(93.0)	(104.8)
Developer Levelized Cost	2009$/ MWh	123.9	181.5	127.6	146.0	169.2	143.0
Developer Premium	2009$/ MWh	(50.9)	6.8	(47.2)	(28.7)	(5.6)	(31.8)

The levelized cost of generating power from the six projects ranged from $58/MWh for Wainiha to $86/MWh for Upper Lihue assuming KIUC ownership. The extended project life assumption for hydro (50 years) gives hydro a slight competitive advantage over the other resources. However, this assumption is justified based on the long record of successful operation of Kauai's existing hydro plants. Compared to KIUC's forecasted avoided energy costs, the levelized cost premiums ranged from ($116)/MWh to ($89)/MWh. The negative premium indicates that developing these resources is less expensive than the forecasts of KIUC's avoided costs. The best project appears to be the Wainiha project, which had undergone extensive development in the 1980s before being halted due to low power prices.

The levelized cost of power with developer ownership was also calculated. The levelized cost premium was still lower than the avoided cost forecasts, but not as low as with KIUC financing. The levelized cost of generating power with developer ownership was consistently higher than the cost with KIUC ownership, despite the advantage of the PTC. This occurs because of the large difference in financing cost between the developer and KIUC. It is noted that more than the other technologies, KIUC ownership of hydro projects many not be feasible in all situations. KIUC will need to work closely with other parties to ensure the most appropriate arrangement.

Mauka

Hydro

Plant Input Data		Economic Input Data	Rate	Escalation
Capital Cost ($1,000)	3,959	First Year Fixed O&M ($1,000)	90.25	3.0%
Total Net Capacity (MW)	2.90	First Year Variable O&M ($1,000)	0.00	3.0%
Capacity Factor	15%	Fuel Rate ($/MWh)	0.00	3.0%
Full Load Heat Rate, Btu/kWh (HHV)	-			
Debt Term	25			
Project Life	50			
		Present Worth Discount Rate	5.0%	
Hours per Year	8,760	Levelized Fixed Charge Rate	5.12%	

Year	Annual Capital Cost ($1,000)	Fixed O&M ($1,000)	Variable O&M ($1,000)	Fuel Rate ($/MBtu)	Fuel Cost ($1,000)	Total Cost ($1,000)	PW Total Cost ($1,000)	Busbar Cost ($/MWh)	PW Cost ($/MWh)	Avoided Capacity Cost ($/kW)	Avoided Energy Cost ($/MWh)
2009	203	90	-	-	-	293	279	74.93	71.36	0.00	111.89
2010	203	93	-	-	-	296	268	75.62	68.59	0.00	121.46
2011	203	96	-	-	-	299	258	76.34	65.94	0.00	131.10
2012	203	99	-	-	-	302	248	77.07	63.41	0.00	133.40
2013	203	102	-	-	-	304	239	77.83	60.98	0.00	139.93
2014	203	105	-	-	-	308	229	78.61	58.66	160.34	146.48
2015	203	108	-	-	-	311	221	79.41	56.43	162.00	155.09
2016	203	111	-	-	-	314	212	80.24	54.31	160.15	159.54
2017	203	114	-	-	-	317	204	81.09	52.27	192.08	155.25
2018	203	118	-	-	-	321	197	81.96	50.32	192.80	164.57
2019	203	121	-	-	-	324	190	82.87	48.45	192.35	168.47
2020	203	125	-	-	-	328	183	83.80	46.66	183.14	166.80
2021	203	129	-	-	-	332	176	84.75	44.95	203.74	163.22
2022	203	133	-	-	-	335	169	85.74	43.30	200.11	168.86
2023	203	137	-	-	-	339	163	86.76	41.73	196.32	159.73
2024	203	141	-	-	-	344	157	87.80	40.22	214.88	164.41
2025	203	145	-	-	-	348	152	88.88	38.78	202.03	166.83
2026	203	149	-	-	-	352	146	89.99	37.39	206.07	170.16
2027	203	154	-	-	-	357	141	91.14	36.07	210.19	173.57
2028	203	158	-	-	-	361	136	92.31	34.79	214.40	177.04
2029	203	163	-	-	-	366	131	93.53	33.57	218.68	180.58
2030	203	168	-	-	-	371	127	94.78	32.40	223.06	184.19
2031	203	173	-	-	-	376	122	96.07	31.28	227.52	187.87
2032	203	178	-	-	-	381	118	97.39	30.20	232.07	191.63
2033	203	183	-	-	-	386	114	98.76	29.16	236.71	195.46
2034	-	189	-	-	-	189	53	48.30	13.58	241.44	199.37
2035	-	195	-	-	-	195	52	49.75	13.33	246.27	203.36
2036	-	200	-	-	-	200	51	51.24	13.07	251.20	207.43
2037	-	206	-	-	-	206	50	52.78	12.82	256.22	211.58
2038	-	213	-	-	-	213	49	54.36	12.58	261.35	215.81
2039	-	219	-	-	-	219	48	55.99	12.34	266.57	220.12
2040	-	226	-	-	-	226	47	57.67	12.10	271.91	224.53
2041	-	232	-	-	-	232	46	59.40	11.87	277.34	229.02
2042	-	239	-	-	-	239	46	61.19	11.65	282.89	233.60
2043	-	247	-	-	-	247	45	63.02	11.43	288.55	238.27
2044	-	254	-	-	-	254	44	64.91	11.21	294.32	243.03
2045	-	262	-	-	-	262	43	66.86	10.99	300.21	247.90
2046	-	269	-	-	-	269	42	68.86	10.78	306.21	252.85
2047	-	277	-	-	-	277	41	70.93	10.58	312.33	257.91
2048	-	286	-	-	-	286	41	73.06	10.38	318.58	263.07
2049	-	294	-	-	-	294	40	75.25	10.18	324.95	268.33
2050	-	303	-	-	-	303	39	77.51	9.99	331.45	273.70
2051	-	312	-	-	-	312	38	79.83	9.80	338.08	279.17
2052	-	322	-	-	-	322	38	82.23	9.61	344.84	284.75
2053	-	331	-	-	-	331	37	84.69	9.43	351.74	290.45
2054	-	341	-	-	-	341	36	87.24	9.25	358.77	296.26
2055	-	352	-	-	-	352	35	89.85	9.07	365.95	302.18
2056	-	362	-	-	-	362	35	92.55	8.90	373.27	308.23
2057	-	373	-	-	-	373	34	95.32	8.73	380.73	314.39
2058	-	384	-	-	-	384	33	98.18	8.56	388.35	320.68

Levelized Bus-bar Cost, $/MWh	**79.07**
Net Levelized Cost ($1,000)	**309.33**
Levelized Avoided Capacity Cost, $/MWh	**-**
Levelized Avoided Energy Cost, $/MWh	**174.74**
Levelized Cost Premium, $/MWh	**(95.67)**

Figure 8-12. Life-cycle Cost for Waimea Mauka Hydro Project.

8.7 Advantages and Disadvantages of Technology

8.7.1 Fit to KIUC Needs

Like wind and solar, hydro is a gift from the earth. The fuel is "free". The disadvantage is that the earth can be fickle and power production is dependent on the consistency of weather from season to season and year to year. Hydro projects with the exception of pumped storage using sea water, are susceptible to drought. This was evident to Kauai hydropower producers during the most recent drought from 2000 to 2002. A total of six years of drought have been experienced on Kauai in the last 100 years.[99] For this reason the variability in hydropower output is large, even compared with other renewable resources.

As an as-available resource, hydro matches the current energy priorities of KIUC, that is, energy and not capacity.

The hydro projects identified in this report are all relatively small and could be easily integrated into the KIUC energy mix. The Upper Lihue upgrade project is an ideal project in terms of compatibility with KIUC needs. As it is an existing site, the necessary infrastructure (roads, T&D) is already in place to accommodate the increased generation. Further, KIUC already owns the plant, and the new turbine installation would be relatively easy and quick.

8.7.2 Environmental Impact

Hydropower's impacts on the environment and, correspondingly, its ability to be cost-effective and licensable are a function of the technology used. In general, project types in order of decreasing difficulty due to cost, environmental and permitting constraints are:

- Storage (new), including pumped
- Run-of-river or (trans-basin) diversion
- Run-of-ditch or storage (existing)
- Plant enlargement
- Equipment upgrade (new or refurbished turbine/generator)

Storage hydro resulting in the damming of rivers can result in significant environmental impacts including interference with fish migration and flooding of sensitive archeological, agricultural, natural or developable lands. Off-stream storage and run-of-river projects mitigate some of these impacts of flooding. On the positive

[99] State of Hawaii Commission on Water Resource Management,
http://www.hawaii.gov/dlnr/cwrm/drought/history.htm

side, storage can provide both valuable flood control as well as recreation areas. Nevertheless, the sources reviewed make it clear that new storage projects are unlikely due to environmental impacts. Hydropower projects which utilize existing storage have the advantage of these impacts already considered in the island's ecology. This is also true for run-of-ditch projects where historical diversions are already captured for power production. Least obtrusive of all are upgrades to existing facilities, either by enlarging the plant's capacity by adding units or simply updating or upgrading equipment to increase flexibility and efficiency. The latter are least subject to environmental concerns since work is completed within existing structures. These projects are sometimes referred to as incremental hydro because they do not alter stream flows.

Unlike wind and solar energy, hydropower does "consume" a competitively pursued agricultural and scenic resource: water. Nevertheless, agriculture, scenic streams and waterfalls can be maintained in part by providing minimum instream flows as laid out in the Hawaii's State Water Code legislated first in 1987. The Code aims at protecting the natural, recreational, scenic, navigation, water quality, irrigation *and hydropower* resources for waters of the State.[100] According to State Representative Mina Morita, to date standards have not yet been set for individual streams in Hawaii.[101] This adds to the uncertainty of calculating benefits of hydropower projects which rely on these base flows for both revenue and reliability.

Permits

Unlike many other renewable energy systems, hydropower often impacts a larger area and is closely tied to the use of larger surface waters which compete with other uses. This typically translates to a larger number of permits. Permits which may not apply to other energy sources, but that will or may be required for new hydropower projects on Kauai are:

- Corps 404 Permit, involves Section 7 Consultation with U.S. Fish & Wildlife and other federal agencies
- State Board of Land and Natural Resources, Stream Channel Alteration, Stream Diversion, and Conservation District Use Permits

Hydropower projects that are upgraded will generally require a smaller number of permits.

[100] State Water Code, Section 174C-3.
[101] Personal telephone conversation with Representative Mina Morita, November 16, 2004.

Sensitive Species

Hawaii has the highest number of federally-listed endangered and threatened species in the United States. There are 317 threatened and endangered species in the state, of which 44 are animals and 273 are plants.[102] Plant and animal species that rely on perennial or intermittent streams are most impacted by hydropower projects which derive their energy source from streams. Many parts of Kauai have been designated critical habitat meaning that they are considered essential for the conservation of a threatened or endangered species. Projects proposed within these habitat areas require special consideration when a federal permit, such as a FERC license or Corps 404 permit, are involved.

In general, all water projects, including hydropower, will involve careful assessment of affected animal and plant species. Some pertinent examples for Kauai are discussed below.

Birds

Many of the animals listed as endangered for Hawaii are birds. Some endangered species are specific to Kauai including those in the thrush and honeycreeper families. These native birds are especially found in the higher elevation of the islands where hydropower development is more likely. One report on the Large Kauai Thrush lists the construction for an un-named dam for hydropower and irrigation as a threat to this bird.[103]

Goby

One species of needed study for hydropower projects is the native goby (*'o'opu*) fish. Five species of native goby occur in streams in the Hawaiian Islands.[104] Although the goby are not listed as endangered, one species was listed as a Candidate species on the Federal Register, and was considered 'threatened' by the American Fisheries Society (AFS). Two other species were considered to be species of special concern by the AFS.

[102] U.S. Fish and Wildlife Service, http://ecos.fws.gov/tess_public/TESSWebpageUsaLists?state=HI
[103] Virginia Tech Conservation Management Institute, http://fwie.fw.vt.edu/WWW/esis/lists/e101023.htm
[104] Hawaii Biological Survey website, http://hbs.bishopmuseum.org/.

Figure 8-13. Native Goby ('O'opu) (Source: Hawaii Biological Survey).

'O'opu have an amphidromous life cycle; they migrate to and from the sea but do not use the ocean for reproduction. *'O'opu* spend their entire adult lives in freshwater streams. They reproduce in the stream, laying their eggs on the upper surfaces of rocks and hatch within 48 hours. Larvae then drift out to the ocean and spend up to 160 days in a planktonic state. Returning post-larval *'o'opu* may ascend randomly to streams and at times in great numbers. Some species are capable of climbing waterfalls and areas of rapids as high as 1000 feet. One species is known to migrate downstream to spawn on riffles located just upstream of the ocean. Downstream spawning runs are believed to be triggered by the first large rainstorm in the fall. However, postlarvae have been found throughout the year, indicating that some degree of spawning occurs throughout the year.

A major ecological requirement for *'o'opu* is the need to pass through a stream mouth at two times during the individual's life. The most important factor for the existence of endemic *'o'opu* in streams is that access to and from the ocean is maintained. Stream channelization and diversions can significantly impact native fish populations within a stream.

Newcomb's Snail

Newcomb's Snail is a federally and state-listed endangered species known to inhabit streams on Kauai. A recent federal rule established critical habitat area for this snail. [105] Significantly, this designation does not conflict with the two proposed run-of-river projects. The Wainiha River was excluded from the Critical Habitat Area for the

[105] U.S. Fish and Wildlife Services, "Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Newcomb's Snail; Final Rule, 50 CFR, Part 17, August 20, 2002.

federally and State Endangered Newcomb's Snail. The North Fork Wailua River below Elevation 1100 feet was excluded from the Critical Habitat Area. The public discussion centered around the establishment of the Critical Habitat Area shows that not only environmental, but also development issues, such as hydropower, are addressed to try to maximize benefits for all uses.

Plants

Most of Hawaii's endangered plants occur in the upper dry and wet forests in small isolated areas.[106] The U.S. Fish and Wildlife Service has established Critical Habitat Areas for 95 non-aquatic plant species on the Islands of Kauai and Niihau. The areas expressly exclude both the proposed sites for the Wainiha and Wailua projects.[107]

8.7.3 Socioeconomic Impacts

The socioeconomic impact of hydro varies. Large hydro projects are massive construction efforts that create many long lasting operations and maintenance jobs. The hydro projects considered here are much smaller and have smaller impacts. Long-term job creation is minimal, although there will likely be 20-40 temporary jobs created during the construction of the new sites (18 to 24 months).

8.7.4 Incentives / Barriers

There are a variety of incentives and barriers to hydro project development on Kauai.

Storage projects can provide valuable flood control. Even run-of-river projects remove flow from natural streams allowing for more controlled releases and the potential for damage to bridges and culverts downstream. Recreational opportunities often follow hydropower projects as access is provided to remote areas for fishing and hiking. Even research and scientific exploration can also be enhanced via additional data from stream gages, weather stations, communications systems, etc. normally associated with hydropower development.

Hydropower is generally viewed less favorably on Kauai than other renewable forms of energy. This may be due, in part, to the dependence of the largest business, agriculture and tourism, on reliable water. Hydropower competes to some extent with this water. Previous experience with potential development that did not adequately address these issues may have left a sense of suspicion about hydropower. These

[106] U.S. Army Corps of Engineers, Honolulu District, Summary Report for Hydroelectric Power, October 1978, p. E-2.
[107] Federal Register, Volume 68, Number 39, Sections 68 and 69, February 27, 2003.

misgivings can only be overcome by environmentally-sensitive projects than leave the door open for agricultural uses.

Hydropower could be seen by others as ancient history since the last new hydropower plant on Kauai, Waimea Mauka, was constructed a half century ago. The last round of proposals in the early 1980's for Wainiha, Wailua and Kokee all proved to be disappointing, which would lead some to believe that hydropower does not have a bright future in Kauai. Nevertheless, these efforts seemed to have failed primarily for economic, rather than environmental or social reasons. Increasing fossil fuel prices and an increasing sense of need for self-sufficiency may tip this balance. As previously stated, hydropower uses both natural and developed sources already available to Kauai which seems to fit the island's philosophy of "use what you got."[108]

Hydro projects, especially run-of-river, can be constructed with a very low profile and can, in fact, be generated underground with little visual impact. This reflects a desire for a "parklike" appearance throughout the island documented in the Kauai General Plan.[109] This is an advantage in a scenic region like Kauai.

This low profile can also be an advantage in areas subjected to tropical storms and hurricanes, where elevated structures associated with wind and solar energy can be exposed to severe loading conditions. No reported damage to hydropower resources has been noted in this study due to the devastating Hurricanes Iniki in 1992 and Iwa in 1982. In fact, it was reported that after Hurricane Iniki, power was first restored on Kauai to the Princeville area thanks to its reliance on Kauai's largest hydropower plant at Wainiha.[110]

Perhaps one of the greatest advantages of hydropower is long life, typically considered to be at least 50 years. Of the seven operating hydro plants on Kauai, all are now over 50 years old, with the Wainiha plant approaching its 100th anniversary. Though equipment must be maintained and occasionally replaced, the very stability of the hydro technology due to its simplicity and high efficiencies means that major upgrades or changes of technology are not needed to continue producing reliable power for many decades.

8.8 Next Steps

To further narrow the selection of potential hydropower projects and fairly compare cost and other factors with other renewable technology, we recommend the following additional sources of information and studies be pursued for projects identified

[108] Telephone conversation with Laurie Ho, Natural Resource Conservation Service, Lihue, Kauai on November 16, 2004.
[109] County of Kauai Planning Department, Kauai General Plan, November 2000.
[110] Personal telephone conversation with Representative Mina Morita, November 16, 2004.

as promising. This effort would bring potential hydropower projects to a feasibility level of study.

8.8.1 Additional Sources

The following sources may prove helpful for a further evaluation of the identified projects:

- Source data for 1981 Corps of Engineers National Hydropower Resources Study Regional Assessment for Alaska and Hawaii.
- State of Hawaii Department of Land and Natural Resources reports on Waialeale and Kokee Hydroelectric Projects
- Additional sources of information for used Department of Energy study assessments
- Power generation records from the Wainiha, Upper Lihue, and Waimea Mauka hydropower plants
- Conceptual design reports, plans, data and calculations prepared by McBryde Sugar Company in the 1980's for Wainiha
- Conceptual design reports, plans, data and calculations available at Gay & Robinson for projects at Waimea Mauka Powerhouse and in the Kokee region.
- Planning documents prepared by Northwest Power for the Wailua Hydroelectric Project.

8.8.2 Feasibility Study

To bring specific hydropower projects to a feasibility level of effort, the following activities are recommended for each selected project:

- Complete one-day site visit
- Perform site specific hydrological studies to develop a powerhouse hydrographs
- Explore site specific constraints with government resource and planning agencies and affected or interested businesses, groups and individuals.
- Develop conceptual design plan from which quantities for construction could be estimated and costed.