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January 28, 2001

EISG Program Administrator
San Diego State University Foundation
5250 Campaline Drive, MC 1934
San Diego, CA 1934

Dear Mr Klein:

In response to your January 2001 Innovative grants RFP, enclosed please find one original and 5 copies of our New Sagebien Project proposal. We believe that the proposal is both unique and innovative, yet addresses a major environmental issue. Power generation often conflicts with fish habitat. Normally this is thought of a problem at high dams. However, small dams (often used as parts of high head projects) are far more of a problem for fish.

High head modern turbines generate nearly all the hydropower in the US and is a logical focus of research. These often have diversion dams associated with them, especially in California. Most fish and fisheries are affected by these lower dams, which may or may not be used for hydropower. This proposal therefore focuses on how to generate power at these low head sites while enhancing fisheries habitat.

This proposal focuses on using a modified breast wheel to both improve fisheries habitat and generate hydropower at the diversions. Increased hydropower becomes a product of fishery habitat improvement. The power byproduct provides a real time incentive to maintain the proper operation of the facility.

We propose to explore an open channel, hydro-powered prime mover that will allow fish to pass both ways through a diversion dam. We know from historical experience that the underlying prime mover will work efficiently, and believe that we can modify it to pass fish both ways. Our proposal addresses the physical testing of a Sagebien water wheel, a design that was perfected in the later 1860s. We hope that this proposal is of interest. It is rare that hydropower can be thought of as a partner in fish passage technology, yet this synthesis gives reason to think that it will work in many small diversion dams across the central valley and around the world.

If you have any questions or further clarification is needed, please feel free to contact us at your convenience.

Respectfully
Davis Hydro

Richard D. Ely, General Manager
Enclosures: Proposal - plus 5 copies

The Sagebien Project

Modifying a Particular
Breast Wheel

to make

A Fish-Passing
Micro-Hydropower Facility

for

Low Head Diversion Dams

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Figure 2b - Wheel with Warped blades on inner rims so that fish can slither up the back side between chambers.

Figure 3 - Elevated Sagebien Wheel with fish and debris passing under wheel. Power coming from reaction mode operation.

Figure 4 - Flooded Wheel with fish passing over top of chambers. Power coming from reaction mode operation.

The Sagebien Project

Summary

Hydropower turbines were developed in the late 19th century without considering their effects on the environment. Turbines and their associated diversion dams form direct barriers to fish migration up and down stream causing mortality and morbidity of species that pass them. Common low head diversion dams are open channel flows. Water wheels allow fish to pass effortlessly down stream, but challenge fish moving upstream except during floods. One type of water wheel, the undershot breast wheel - and the Sagebien Wheel in particular - might be modified to allow fish to pass both ways and still efficiently generate hydropower.

Our research will be to design, build and test a specific undershot wheel modified to pass fish. We will test the wheel for both power and fish passage at the UC Davis Hydraulics Lab. Secondarily we will also be testing a new method to remove power from the wheel via a rim chain drive.

If we are successful we will have produced a wheel that can be used in the hundreds of diversion dams throughout California and thousands of dams around the world to generate power and restore fisheries that have been destroyed by the smaller diversion dams.

The Sagebien Project

Background:

Why a water wheel?

Water wheels keep the water at atmospheric pressure and keep it moving in the same direction, which is essential for fish attraction. If an undershot wheel is used – a breast wheel in particular – and the blades are kept short with fish passages in them, it ought to be possible to design a breast wheel that passes fish in both directions. Specifically, this proposal will test a redesign of the Sagebien breast wheel to pass fish in two directions while continuing to provide hydropower.

To accomplish this objective we propose to test a water wheel that slightly predated the Francis turbine in design. Specifically, we propose to test a specially engineered Sagebien breast wheel. The Sagebien wheel was designed solely for efficient hydropower production. It was very efficient even by modern standards (kw out/cfs*head in). Unfortunately, its efficiency was limited by two factors:

Material per kW: The material cost per kW of the Sagebien wheel went up at least linearly with the head. For a Francis turbine the size and cost drops roughly linearly with head. This means that the undershot wheels are only practical and competitive with turbines at low heads.

Low RPM: The Sagebien wheel delivers shaft hydropower at very low RPM. This is always a disadvantage for there were few applications then and now, which can use power at very low RPMs. However it is an advantage for fish. The Sagebien wheels move very slowly relative to fish allowing the possibility for the fish to pass up through the turbine if it were designed correctly.

The Problem:

High head dams generate large amounts of power and are very visible symbols of the controversy between hydropower and fish. Low head diversion dams are far more prevalent because they are often used as part of a hydro development, as well as for many other reasons. Low head dams are very common throughout California and the world.

In California diversions are common for hydropower. Good examples are the Cresta Rock Creek Project on the North Fork of the Feather River, or any hydro project on the Pit River.

As common as diversion dams are when used for hydropower, they are even more commonly used for agriculture. Many rice paddy, cotton field diversion and small diversions may not even be recorded on a global scale because they are only three feet high. Each of these dams, however small, is a major barrier to fish migration and is destructive to habitat. Recent reviews (Clay 1995, Jungwirth et al. 1998, Odeh 2000) document the renewed interest in safely passing migrating fish past a wide range of human-constructed structures in flowing water. Worldwide, structures (including dams and fish screens) may be associated with water storage, flood control, hydroelectric power, agriculture and especially paddy irrigation, among other uses.

Diversion dams completely change parts of flowing (lentic) systems to non-flowing (lotic) ones, disrupt fish movements and change fish communities (Li et al. 1987), including possible extirpation of species (Winston et al. 1991). Turbines are commonly observed to be responsible for fish injuries and deaths (Stokesbury and Dadswell 1991, but see Mathur et al. 1994). If they can be modified to pass fish and eels in a manner that generates power, the power generated will compensate for the complexity of the design. More importantly, the power generation provides incentive for their maintenance because with our design, if the wheel is generating power well, it will pass fish well.

The question to be explored in this research is: "Can the Sagebien breast water wheel be modified to become an environmentally friendly hydropower recovery device for use as a diversion dam? If modified to pass fish in two directions, will it generate significant power?

Our Project Statement

In this project we will construct a modified Sagebien wheel approximately 2.5 feet in diameter. It will have been modified so that there is good possibility that fish can pass two ways. It will be tested in a fresh water flume at the UC Davis Hydraulic test Laboratory on the campus at UC Davis.

The results of our research will be released into the public domain. We will endeavor to promote the idea by making the design available to any user. Complete disclosure will be made through a Web page, publication of a paper and other means as directed by CEC. If some success is achieved, we also expect one or more professional papers to be published by faculty of the university and possibly through theses written by students helping with the testing.

Since the design of the Sagebien wheel has been in the public domain for about a hundred years, and the design of various fish passages are public, we expect no difficulty in publishing the results of testing.

Description of New Turbine

The Sagebien is a particular type of breast water wheel with four attributes that make it applicable to the resolution of some low head fish conflicts with power production. The original Sagebien Water Wheel was developed in the 1860s in France. The original turbines were built in Europe and still exist in ruins in many mills in central France. Several of these were visited by the author who found the original wheels still in place in mills on the Mayenne and Sarthe Rivers of the Loire Valley in Northern France. The previous tests of the turbines power were done and described in the references in Appendix A & B. The reported efficiencies were in the 85 to 90 percent range.

The Sagebien wheel is described at length in the articles in Part 1 of Appendix A, and most clearly in English in the article in Appendix B. It was the most efficient water wheel of any type. Its efficiency is arguably greater than that of a modern high speed turbine, and certainly greater than a modern turbine operating at a head less than 4 feet.

For our design purposes, the typical wheel is designed for heads of about 3-5 feet. This drop is on the high end for canal drops in irrigation channels, and on the low end for diversion dams. It is perhaps the most common height of check dams, control weirs and diversion dams in the world. These can be easily seen in every irrigation canal in California, and all over the orient for diverting waters for agricultural purposes.

The original Sagebien wheel, as shown in Figure 1, has a series of vanes that fill slowly as they turn. The slow filling at atmospheric pressure makes them ideal for carrying small young fish downstream. As originally designed, the blades are too numerous and too high to allow the wheel to be used as an upstream fish passage, but by shortening the blade height, and by decreasing the number of blades (shown in Figure 2), and changing the blade's shape and back surface it might be possible to modify the wheel both to generate power, and to allow fish passage upstream as well as down. It is basically a topology problem to redesign the blades so that they provide a fish passage. If the Sagebien wheel were modified, fish could pass upstream in three modes:

a) By jumping or slithering between the chambers formed by the modified blades. For this to occur we will make the blades in the form of wet ramps that would induce fish passage. Figure 2b shows the wheel with some of the blade inner rims curved and twisted to allow for water to pour diagonally down the back surfaces. The movement of the water and the surface might provide the motivation and the means for fish to move upstream.

b) By swimming under the wheel between the wheel and the breast (Figure 3) when there is sufficient flow or fish. This elevated mode clearly would generate less power, but power may be limited in flood conditions due to rising tailwater.

c) Or at high water, by swimming up the water flowing over the tops of the blades (Figure 4) if the wheel is not raised.

Modes "b" and "c" have hydraulic losses that detract from efficient hydropower production. The only time that modes "b" and "c" have to be used is when these species are migrating upstream. For the rest of the time, mode "a" can be used with no power loss. The following is a list of the conceptual paradigms of this fish-friendly hydro technology to be explored in this testing study:

- The Sagebien wheel is hydraulically very efficient at generating power when operating in mode "a".
- It has low turbulence and water column mixing in mode "a", encouraging juveniles to pass through.
- There are no large velocity gradients or pressure changes, which allows for the safe downstream passage of fish in all modes.
- It turns slowly which will permit fish passage upstream in mode "a".

Research Objectives

The proposed Sagebien water wheel project will test upstream and downstream fish passage in a laboratory flume past the (small-scale) power-generating device (the water wheel). This has not previously been done. While fish passage downstream is expected to pose no surprises, it has to be tested. The main focus of testing will be real design modifications that will allow the passage of fish upstream. We know that some fish will pass through keyhole gaps upstream as shown in Figure 2a but they often stop to rest. We know that some will rapidly shoot up pass up shallow riffles, if the bottom is of the right texture. The question under test here is, “Can the blades and chambers be designed in a way to encourage fish to pass upstream in one or more ways while the buckets are slowly descending?” Under what conditions can we construct a diversion dam that is transparent to fish? Can significant power be generated while we pass fish?

If it can be done, we will have a technology that will allow diversion dams to not only pass fish but to generate power that will help with maintenance.

Proposed Research Methodology

We will build at least one scale model of the Sagebien wheel and modify it with different combinations of fish slot and blade height. Modifications for the model test include:

Reducing the number of blades to form an effective fish ladder as suggested in Figure 2a. The blades might be notched in a zig-zag pattern to create a steady water stream for fish passage.

Reducing the height and configuration of the blades so that fish and water can pass over them going downstream Figure 3, and fish can jump over them going upstream. Note that water enters and exits normally by the bottom of chambers. This permits the top of the chambers to be designed as a riffle surface suitable for some species to slither up. The new blades will have back surfaces and curvatures Figure 2b.

Designing supports to allow rapid raising of the entire wheel during conditions of high discharge, debris transport, or a public safety incident (Figure 3). This would also allow occasional raising of the wheel so that non-jumping fish could swim under it. It will also allow for flood flows as is necessary in a full size application.

Provide sufficient strength to allow efficient power generation while flood waters pass over or around the blades (Figure 4).

Use a new balancing wheel supporting structure to reduce weight, enhance control, and efficiency. The original Sagebien designs were heavy due to the materials available at the time. We will use modern materials that will allow a robust design, simplify maintenance, and make power recovery efficient. Maintenance is a key design feature.

Testing Plan for Fish Performance

Fish will be obtained from field sites or hatcheries, as available. Holding tanks and fish handling equipment is present at the lab. Species used will be either native resident stream or river fish (e.g., rainbow trout, Oncorhynchus mykiss; Sacramento pike minnow, Ptychocheilus grandis; Sacramento sucker, Catostomus occidentalis; splittail, Pogonichthys macrolepidotus) or anadromous fishes (e.g., steelhead; the anadromous form of rainbow trout]; chinook salmon, Oncorhynchus tshawytscha) that are known to migrate in California streams. They will be transported quickly from the collecting site to the laboratory in oxygenated, plastic containers, and held in round fiberglass tanks with continuous flows of unchlorinated well water (19ºC; dissolved oxygen concentration > 90%, with respect to air saturation levels) and air (via diffuser stones). Fish will be fed appropriate pelleted or flaked diets, and they will be examined before experiments to check for injuries or other evidence of poor condition.

Fish will be placed upstream and downstream of the operating Sagebien water wheel in the laboratory flume. Fish will be introduced (via plastic containers of water, in groups of three) and they will be allowed 30 min to explore and adjust to the flume prior to the start of the water current (and consequent rotation of the water wheel). The fishes' movements will be observed by eye under daylight (ca. 300 lux, via laboratory fluorescent lighting and laboratory skylight panels, during daylight hours) and night (ca. 0 lux, laboratory lights off, during night-time hours) conditions. Measurements will be made of the frequency, time, and direction of the fishes' movements past the water wheel, when the flume is operating at each of three velocities (10, 20, 30 cm/s), throughout the 30-min experiments. Also, comments on the fishes' behavior will be recorded (e.g., including tail beat frequencies) to estimate relative swimming effort. Measurements of fish movements (frequency, time and direction past the water wheel) and quantified behavioral observations (e.g., tail beat frequencies) will be entered into spreadsheets for statistical analyses. Sufficient replicate groups (e.g., 6 of each species tested) of three fish will be used to compare results using suitable parametric (e.g., ANOVA) and non-parametric (e.g., Kruskal-Wallis) models.

When one envisions a water wheel the first image is of the water pouring over the top of the wheel and being carried down with the top of the wheel going down stream. The breast wheel works in just the opposite manner. Water comes into the wheel from the side and is lowered with the top of the wheel turning upstream. The Sagebien wheel is a breast wheel. Its outer edge is in very close proximity to the bottom of the flume, and uses the sides and bottom of the flume as parts of the passage. This requires a breast (the bottom of the channel) to be constructed for the modeling out of PVC and fiberglass/epoxy. We may also be testing an inflatable breast designed to deflate during storm flows and allow for the direct passage of fish.

Test Plan for Power

For power measurements we will use a common mechanical Prony brake and tachometer. The break will be manually constructed and since we will be generating only a few hundred watts in the scale model a mechanical water-cooled brake will suffice. RPM will be measured electronically using the laboratory's equipment, or the Leader LDC 822 period/frequency counters belonging to Dr. Ely. Dr. Ely used a similar test set-up on an earlier DOE funded project in the early 1980s, for developing a Crossflow turbine.

Water flow will be measured by existing orifice flow gauges calibrated by the weight tank. The UC Davis Lab is set up with all of these types of equipment.

Expected Results Based on Downstream and Upstream Fish passage

While the historic Sagebien wheel shown in Figure 1 is an efficient breast wheel, we expect it can be modified to:

- Permit safe fish passage up and down stream through the main flow of the wheel. Downstream because there is neither change in flow direction nor pressure on the fish in the downstream current. Upstream because the wheel turns slowly and can be modified to allow fish to pass upstream using three different techniques.
- Maintain pond elevation upstream under changing flows and migration requirements.

- Easily adapt to changing conditions by allowing dynamic control of the wheel height, and possibly speed, unlike fixed height fish ladders.
- Extract power efficiently after fish passage modifications.

Specific Tasks

Task 0 Accept contract and execute subcontract with UC Davis

Task 1 Review wheel and fish passage parameters for wheel design

Task 2 Review modifications to flume, power and fish testing

Task 3 Construct wheel and test cassette with Prony brake

Task 4 First initial power tests and tests for fish passage

Task 5 Review results and modify or rebuild wheel. Modify the fish passages and fish passage surfaces iteratively to determine the best balance of power and fish passage.

Task 6 Final contract tests and evaluation of fish passage, power and future work

Task 7 Final report and project closeout

Test Equipment and Facilities:

The UC Davis J. Amorocho Hydraulics Laboratory

The University of California, Davis' J. Amorocho Hydraulics Laboratory has been conducting hydraulic investigations for over thirty years through simulation and scaled models for water resources projects in California as well as in other States such as Hawaii. Most of the hydraulic model studies in the California State Water Project from the 1960s to 1980s were conducted in the UC Davis Hydraulics Laboratory.

As people pay more attention to the existing ecological and operational problems related to various types of hydraulic structures in the 1990s, the laboratory has performed several interdisciplinary studies strongly related to environmental fluid mechanics, combining hydraulic investigations with ecological studies. Starting from 1994, the laboratory has been renovated by funding from CA DWR, and has been conducting the fish treadmill hydraulic model studies for the California Department of Water Resources and CALFED. This research was also supported by the Interagency Ecological Program (IEP), Delta Fish Facilities Development Team (DFFDT). The Laboratory has recently been involved in various hydraulic modeling studies such as a flood modeling study for Gorman Creek, and the scaled hydraulic modeling study of the inlet structure of Devil Canyon hydropower plant second after-bay.

Facilities and Equipment in UC Davis, J. Amorocho Hydraulics Laboratory:

- Total Laboratory Area
    - 1 acre; indoor working area of 15000 sq ft;
    - Offices occupy 5000 sq ft.;
- A network of underground channels for water circulation;
- An indoor underground water storage tank (a sump with 50000 gal. capacity) and an outdoor reservoir;
- Rotating Rating Tank for the calibration of velocimeters;

- Open channel research facility (incl. gates, weirs, etc.) designed for the California Aqueduct, with a discharge capacity @ 10cfs;

- Two indoor flumes for studies of open channel flow, sediment transport, side weirs, small hydraulic machinery, fish behavior, etc.

- One of these flumes is a 2-ft wide glass, self-circulating flume with tilting capability, which is ideal for testing small hydraulic machinery, and studying fish behavior at small scale. This is the flume that we will use.

- Fish Holding Facilities with nonchlorinated water supply;

- Wind Tunnel;

- Pumps: a) 50 HP @ 18 cfs; b) 50 HP @ 11 cfs; c) 20 HP @ 7 cfs ; d) 10 HP @ 1.1 cfs; e) 3 HP @ 0.8 cfs.; a water well with a pump of 10 HP @ 0.4 cfs

- Major Monitoring Equipment:
  - 2-D electromagnetic current meter
  - 3-D acoustic Doppler velocimeter
  - Propeller current meter
  - Ultrasonic flow meter
  - Thompson Weirs, Parshal Flumes and proportional weirs, etc.

Ability of the facilities to accommodate the testing

The 2-foot flume is operational and scheduled for use in a fish migration study. The flume can be tilted up to 6' on one end allowing fine control of head and tail water conditions. The flume is constructed of glass to facilitate visual observations of the fish, measures 60 cm wide x 45 cm high x 14 m long, and will be filled with 19°C water (dissolved oxygen concentration > 90%, with respect to air saturation levels). The modifications required to test a water wheel include construction of some cheeks for higher head on the up-stream side, and building the bottom up into an appropriate breast for the wheel. Most of the flume will not be modified, but used to provide the up and downstream conditions to condition the fish.

The power measurements will be made using a standard water-cooled Prony brake arrangement constructed on the PTO shaft of the wheel. We do not anticipate using the axel of the wheel.

Applications and Marketability:

Applicability of results

As single units, the Sagebien wheels may be applicable to all sites where there is between 2 and 8 feet of head. The Sagebien wheel has been tested extensively in the 3 to 10 foot range of heads, and with modern material and methods may be extendable outside that range. This makes the wheel applicable to all dams, and irrigation and water supply canals where check dams exist. To use higher heads multiple wheels might be used in series like current fish ladders.

An upper limit in size may be approximated by the 10 megawatt hydro potential at Red Bluff Diversion Dam on the Sacramento River which is now left open most of the year for fish passage. A lower limit is limited by the economics of maintenance, and could be less than 2 feet on an irrigation canal check dam. In the future, if this initial work is successful, we intend to target the Red Bluff dam. But before we get there, this technology might incrementally replace sections of a fish ladder.

Target Market

Small Scale: The target market for this technology is canal drops, locks and existing canal check structures. The units will be designed to deliver moderate speed shaft horsepower to generate electric power.

Larger scale: Agencies that divert water all over the world use structures similar to Red Bluff, or smaller. These agencies, while once omnipotent, are now realizing that these structures are destroying many local as well as distant fisheries. Our technology will provide an environmentally acceptable alternative to the turbine at diversion structures up to about 12 feet of head. The technology is promoted for any location with modest winters where there are, or could be, fish. It is ideal for retrofitting in old locks, canals, and existing water supply conduits.

In summary, the Red Bluff Diversion Dam and the myriad of small diversion structures all over this area of California allow us to focus on real sites, real engineering problems, and be involved with real agencies struggling with the problems addressed by our technology. Our engineers will build on existing technology, with clear direction and the motivation to adapt this traditional hardware to meet this pressing environmental problem.

Project Management and Team

Richard D. Ely, Ph. D. -------- Co-PI
Project Management, design and power testing
Prof. Joe Cech ....Co-PI
Fish performance and wheel design for fisheries goals
UC Davis PI
Jay Boeri , PE ....
Mechanical Design
Prof. Arthur Williams
Undershot wheel transmission design
Additional Lab Staff (un-named):
Students, drafting, secretarial
Team members other than Dr. Ely and Dr. Cech will be acting as consultants and may be replaced with the consent of the CEC.

All parties have agreed to participate in the tasks described.

Organizational structure

The organizational structure is as follows:

Davis Hydro contractor: Dr. Richard D. Ely, sole proprietor
Reporting To Dr. Ely are:
Draftsman, part time
Typist, part time
Bookkeeper, part time
Mr. Boeri - Independent Consultant
Dr. Cech - Independent Consultant
Dr. Arthur Williams - Independent Consultant

Contracted by Davis Hydro
The University of California
Hydraulics Lab including Bill Hartman and staff
Machine shop time

Task Assignment

Dr. Ely will be the overall project manager. He will also be responsible for all budgetary, budgeting, and final reporting tasks. Dr. Cech is an expert in fish kinesthetics and knowledgeable not only about salmonid migration but more generally about fish requirements for local migration between habitats. He will direct all fish performance tests and be responsible for fish performance measurements and reporting. Dr. Kevvas will be responsible for all activities in the lab and any lab staff. Mr. Hartman will supervise day to day operation at the lab.

Fish Passage Task:

The fish requirements oversight task will be led by Dr. Cech. All questions concerning fish acceptability will be addressed from Dr. Cech's experience with other fish passages and with the study of fish behavior in other fish diversion studies. Fisheries monitoring is a part time supervisory task that spans the project in guidance and supervision. The task is to monitor the testing so that the needs of the fish are always a major component of the design. Dr. Cech will supervise the entire project from beginning to end, in a reviewing and consultative capacity.

The model construction is the responsibility of Dr. Ely and Mr. Boeri, because they have had the most experience in building physical structures in water. They have worked together on four sites in New England. Further, Mr. Boeri has extensive practical hydro construction experience, and Dr. Ely has experience building Crossflow turbines and in designing and operating hydro sites.

Financial Structure

Davis Hydro is a sole proprietorship owned by Dr. Ely. It is set up to be the research, development, and operating company for Dr. Ely's hydro projects in California.

Staff -

See Appendix D for short resumes

Dr. Ely is in the preliminary stages of licensing small sites for hydro development in California, as he has done in Connecticut and New York. Corporations owned or controlled by Mr. Ely have had two FERC licenses. One is being relicensed.

Dr. Ely has been in the hydropower business for 25 years. He is the owner of an operating site in upstate New York and is licensing another site in central Connecticut. Prior to this he was in partnership with Mr. Bill Johnson with whom he produced 21 cross-flow turbines from a shop in Rhode Island, using a design that resulted from an early study by the DOE. He installed the last of these turbines in Kosrae, Micronesia. He headed manufacturing at the turbine company, and formerly supervised environmental survey teams over much of the globe. His ability to follow through in "hands-on" projects is demonstrated by his having built or rebuilt three world cruising sailboats and sailed them over much of the tropics.

Dr. Ely has advanced degrees in geophysical engineering, resource economics, and a PhD in Resource Economics from the U. of Connecticut. He has extensive experience in computer simulations, data management, marine equipment design, marine project engineering, marine geophysical field instrumentation, and data collection and analysis. He worked in the public regulatory sector in New England, in the utility sector for Northeast Utilities, on utility cost and capital structure issues for intervenors in power plant licensing hearings, in the environmental sector on fisheries issues, and on solar and electric power issues for environmental organizations.

Mr. Boeri is Registered Professional Engineer and heavily involved in designing and supervising construction of multiple hydro sites in New England. He has an extensive history of success, including the design and construction of his own high head site and the building of computerized control systems for Osberger.

Dr. Cech is a Fisheries Biologist at UC Davis. He has an extensive history looking at the kinesthetics of fish in Lotic and Lentic environments, He is knowledgeable about fish passage and diversion dam fish screen design problems and has spent much of his career working with various state, federal and local government agencies, and public interest groups in attempting to resolve these issues. Currently, he has a complete fish diversion dam simulation test setup at UC Davis and will draw on this resource to provide the expertise and fish stock resources we need for this project. We have stretched the rules and left a nearly complete resume of the Co-PI in Attachment D for reference.

The proposed team is living in or near Davis, California except for Mr. Boeri. Davis, the home of one of the branches of the University of California, is at the southern end of several of the major declining salmon populations.

In summary, the proposal is to test modifications to the Sagebien wheel that allow it to extract hydropower benignly allowing fish passage up and down stream through the wheel. We will show how it can be operated to achieve fish passage and power recovery. We will explore new materials, new engineering and new transmissions to improve the most efficient and environmentally friendly breast wheel ever built.