Preliminary Plan for Gravity Driven Field Irrigation System Based on Collected Run-off Rain Water with Significant Add On Features

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Goals of Presentation

- To Show Water Management Board features of System as was planned for one farm in 1990s
- To advocate for using gravity fed systems in Kentucky
- To relate that system was not implemented due to owner financial limitations although financial justification was supported
- To indicate that system has area/region wide value to Board's challenge
- To advocate for an engineering team to study "proof of concept"
  - and if established to study "feasibility" and
  - if established to install a "prototype system" and
  - If proven proceed to "marketing."

Gravity Feeding Attributes

- Gravity is more or less free power – effortless, reliable, permanent, renewable
- Ancient Technique
  - Romans
  - Anasazi Indians
  - So proven by time
- Costs of system installation and operational maintenance are up front
  - Design and installation is main cost
  - Operational maintenance costs extremely low

Romans

Roman Hydraulic Technology

The achievements of the Romans in impounding, moving and delivering water on a large scale were not matched for 1,500 years. The aqueduct systems in particular embodied many remarkable feats of engineering

by Norman Smith

The Romans have come down in history with the reputation of having been particularly good at engineering. Their various waterworks show that the reputation is justified. Indeed, their achievements in impounding, moving and delivering water (often over long distances and in spite of numerous obstacles) were not matched for some 1,500 years after the decline of the Roman empire.

A good place and time to begin a consideration of Roman waterworks is Rome at the end of the first century. In A.D. 97 a new man took over as water commissioner of the city. He was Sextus Julius Frontinus, who had at one time (A.D. 74 to 78) been the governor of Britain and was the author of works on land surveying and warfare. For seven years up to the time of his death he worked hard to bring a measure of order and efficiency to the operation of a public utility that had been mismanaged and neglected for years. In *De aquis urbis Romae* he set down his experiences in running the largest public water-supply system in the ancient world.

By the end of the first century Rome was supplied by nine aqueducts. The oldest of them, the Aqua Appia, had been built more than 400 years earlier; the most recent, the Aqua Claudia and the Aqua Anio Novus, had been in and out of service for less than 50 years. The bulk of the water supply, and all the water of the best quality, came from the valley of the River Anio (from the river itself and from springs). The lengths of the aqueducts varied from 12 miles to more than 50; in all, Frontinus found himself responsible for some 300 miles of covered channel (*specus*) with cross sections that varied from about nine square feet to as much as 40 square feet.

The popular picture is that Roman aqueducts were carried throughout their length on the tops of lines of arches. Such a picture is quite misleading. As far as was practicable—and the Romans were eminently practical engineers—the routes of aqueducts, at Rome and elsewhere, followed a steady gradient at or below ground level. The use of tunnels, long arcades, high bridges over river valleys or pipelines across deep depressions was a last resort when difficult conditions could be met in no other way. Indeed, the evidence is clear that Roman engineers would go to some lengths, quite literally, to avoid any compromise of their basic rule. In the system of aqueducts serving the city of Rome, for example, only about 5 percent of the mileage was carried on bridges.

Surface and underground conduits were easier to build and to maintain. Access for the cleaning and repairing of underground conduits was provided at intervals along each *specus* through shafts or openings called *putei*. The debris cleaned from the aqueducts was dumped beside the *putei;* modern archaeologists have been able to find the long-abandoned conduits below by identifying these piles of stone, gravel, silt and calcareous deposits.

In order to maintain the required gradients five of Rome's aqueducts had to be carried for a few miles on bridges, the magnificent arcades that are still such a dominating feature of the Campagna. Expediency prevailed, and so the five conduits utilized only two bridges. The Aqua Tepula and the Aqua Julia were carried on the bridge first built to support the Aqua Marcia, and the Aqua Anio Novus shared the bridge of its contemporary, the Aqua Claudia. In purely constructional terms such extensions were not difficult to build; it was simply a matter of putting a new channel (or two channels) on top of the existing one. Concrete faced with brick served for the channels of the Aqua Tepula and the Aqua Julia above the Aqua Marcia, and brick lined with watertight concrete carried the Aqua Anio Novus over the bridge of the Aqua Claudia.

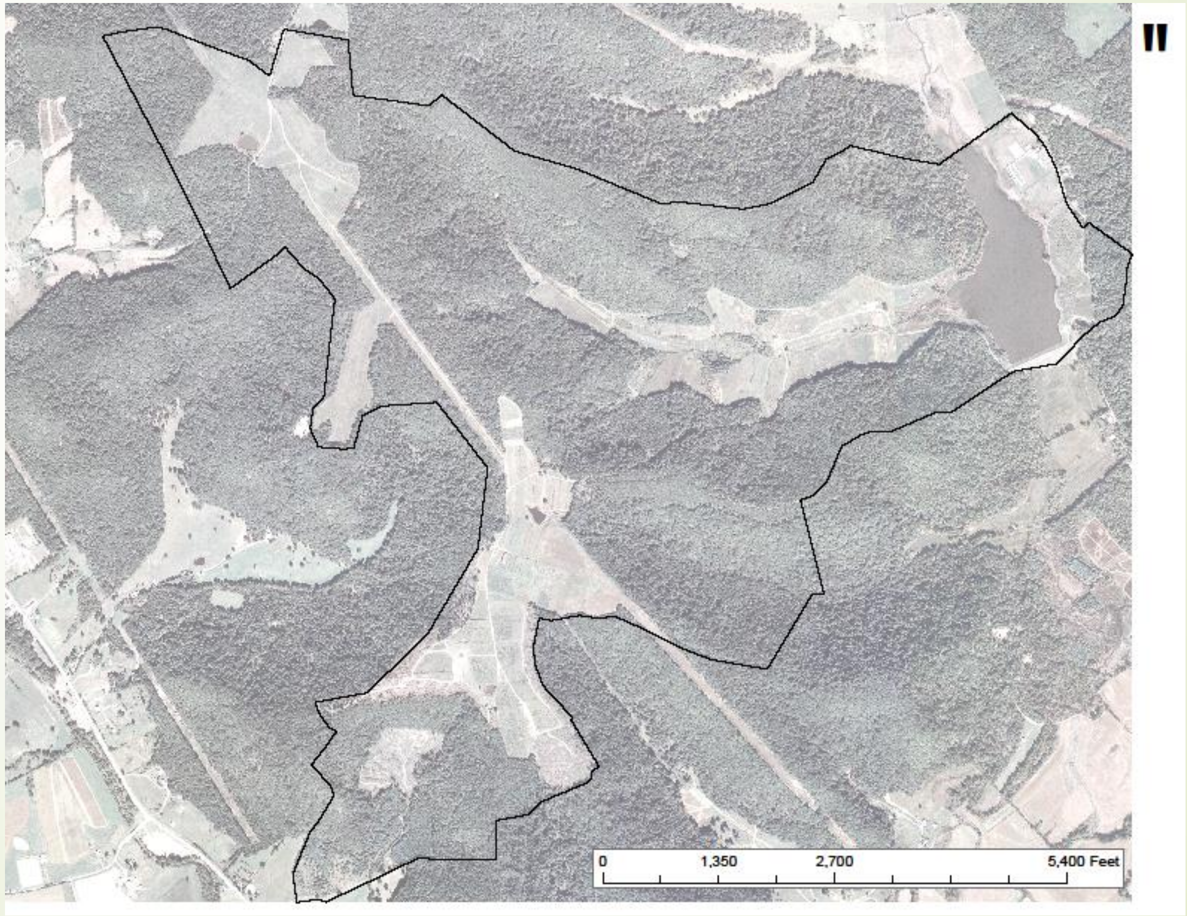
In the long run the elevated sections of aqueduct were not an unqualified success. Both archaeological and written evidence indicate the need for extensive and frequent repairs, which entailed lengthy interruptions in the flow of water. Frontinus comments on the damage resulting from "defects in the original construction." For example, the Aqua Claudia (which was 14 years under construction) was completed in the year 52, repaired in 71 after 10 years of use and nine of disuse, repaired again in 80 and worked on once more in 84. The evidence of such remedial work is manifest in the sections of the Aqua Claudia that still stand. Many of the arches have been crudely built up with thick layers of brick, tile and mortar that often extend several feet down the piers.

The root cause of the problem is obscure. Conceivably the superposition of one or two channels on an existing bridge proved to be too much for the supporting arches, causing joints to open up. Alternatively, increasing the load on the piers may well have led in time to differential settling and consequent overstraining of the arches. Frontinus, who was conscious of the effects of temperature, observes that an advantage of underground channels is that "they not being subjected to either heat or frost are less liable to injury."

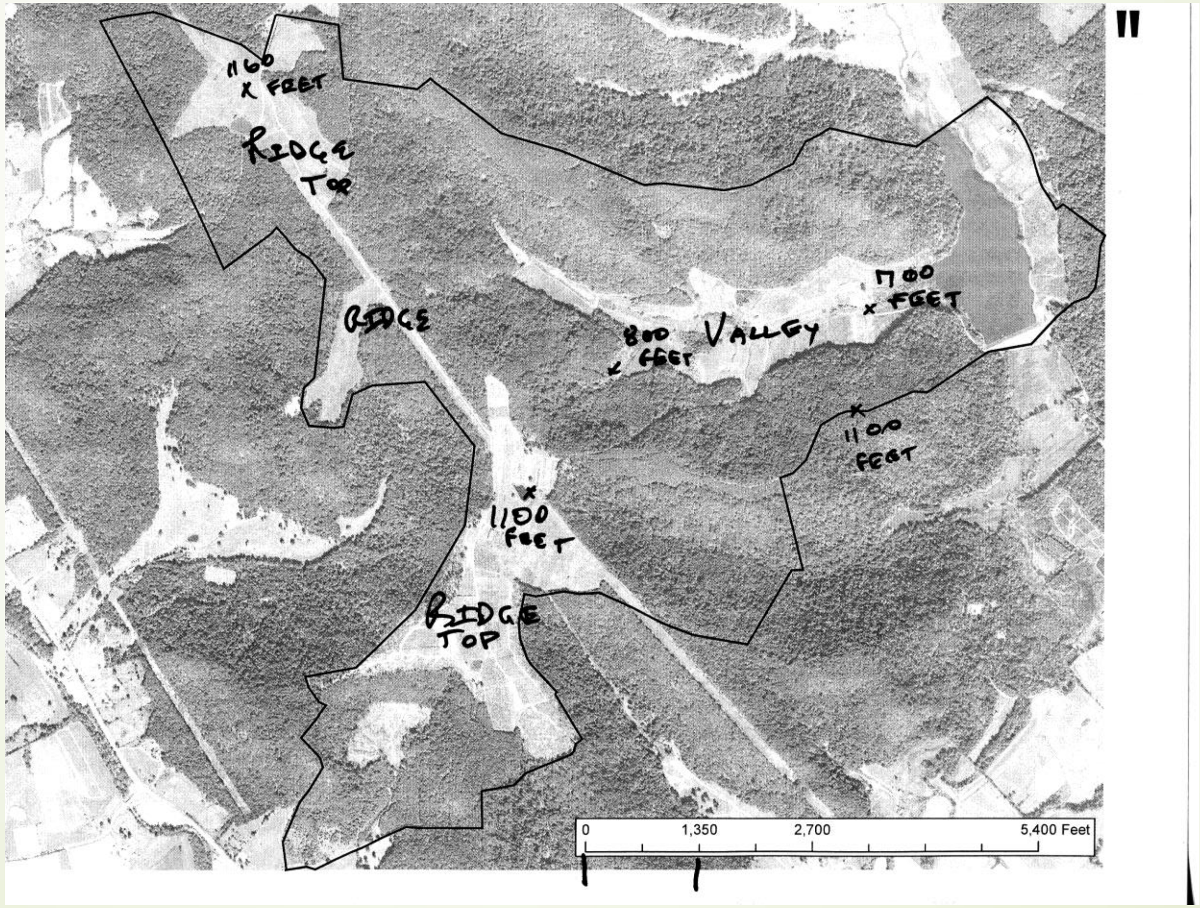
In any event the upshot of these and other structural failures was leakage, which, together with the theft of water from the open channels and from the buried sections if they could be reached and penetrated, resulted in substantial reductions in the volume of water finally delivered to Rome's private citizens and public cisterns. This was the issue that occupied Frontinus more than any other. In the end it defeated him, not least because he was unable to calculate either the theoretical or the actual quantities of water flowing. (Remarkably, Frontinus was under the impression that the volume of flow was a function only of cross-sectional area, depending not at all on velocity. Whether or not such ignorance was confined to civil servants is impossible to test in the absence of a single surviving word from a Roman hydraulic engineer.)

What can a modern calculation tell us of the quantity of water delivered to Rome's inhabitants, who in Frontinus' time may have numbered perhaps a million? The answer is nothing; the data available fall far short of the minimum

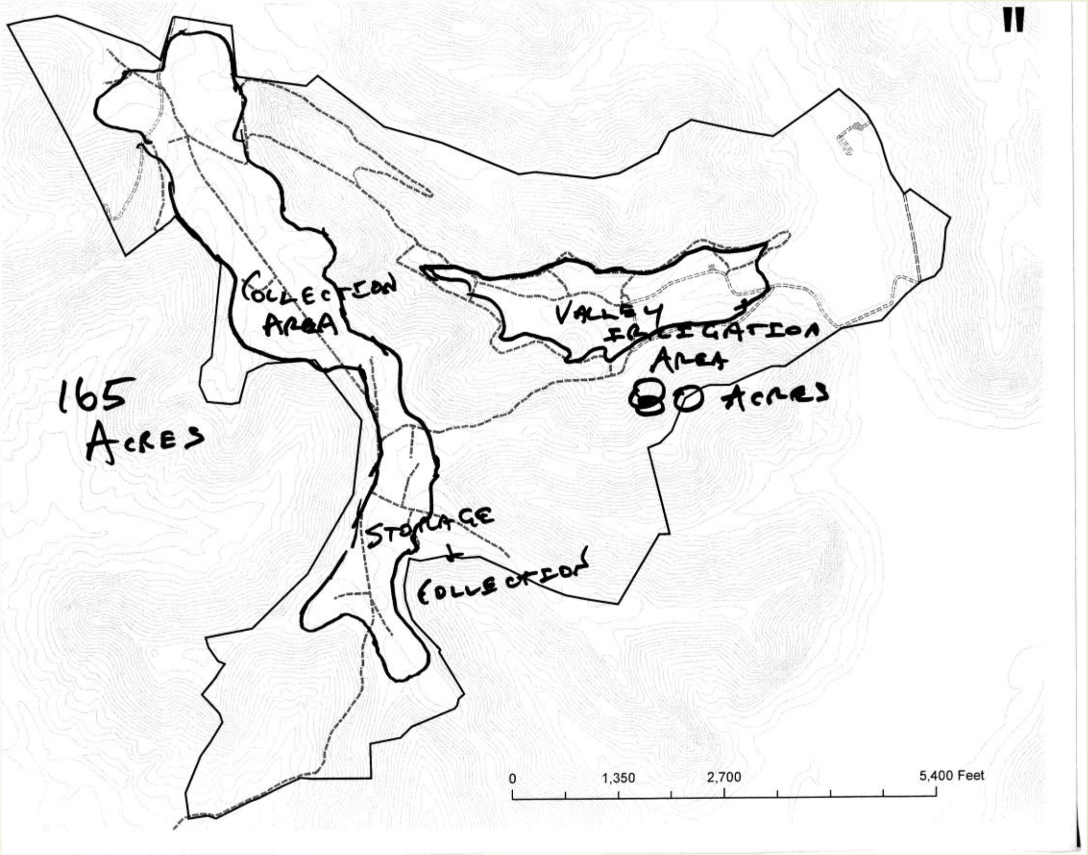
To Demonstrate begin with Hutton & Loyd plan in early 1990s - Farm Boundary on Aerial Photograph – 1124 Acres



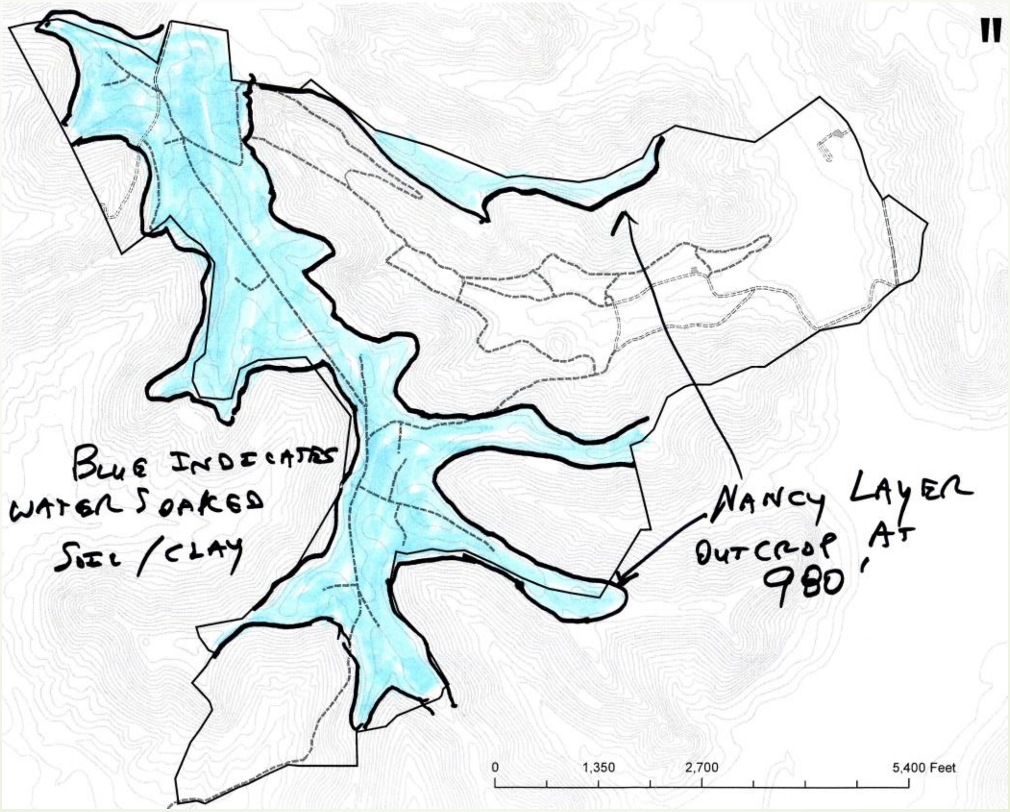
Key Attribute – usable geography: Table top like ridge and 400 foot drop within ¼ mile to irrigation fields



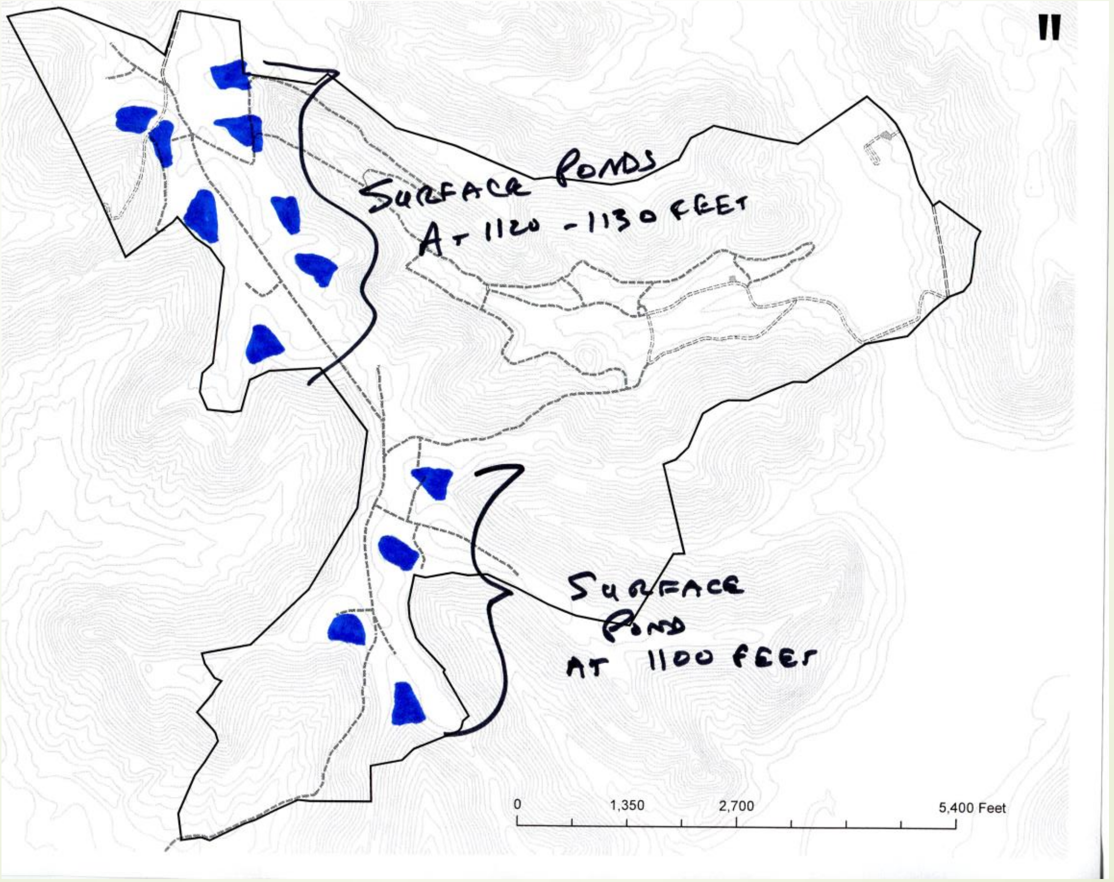
Use this geography for rain water collection on ridge top in ponds and irrigate in valley fields



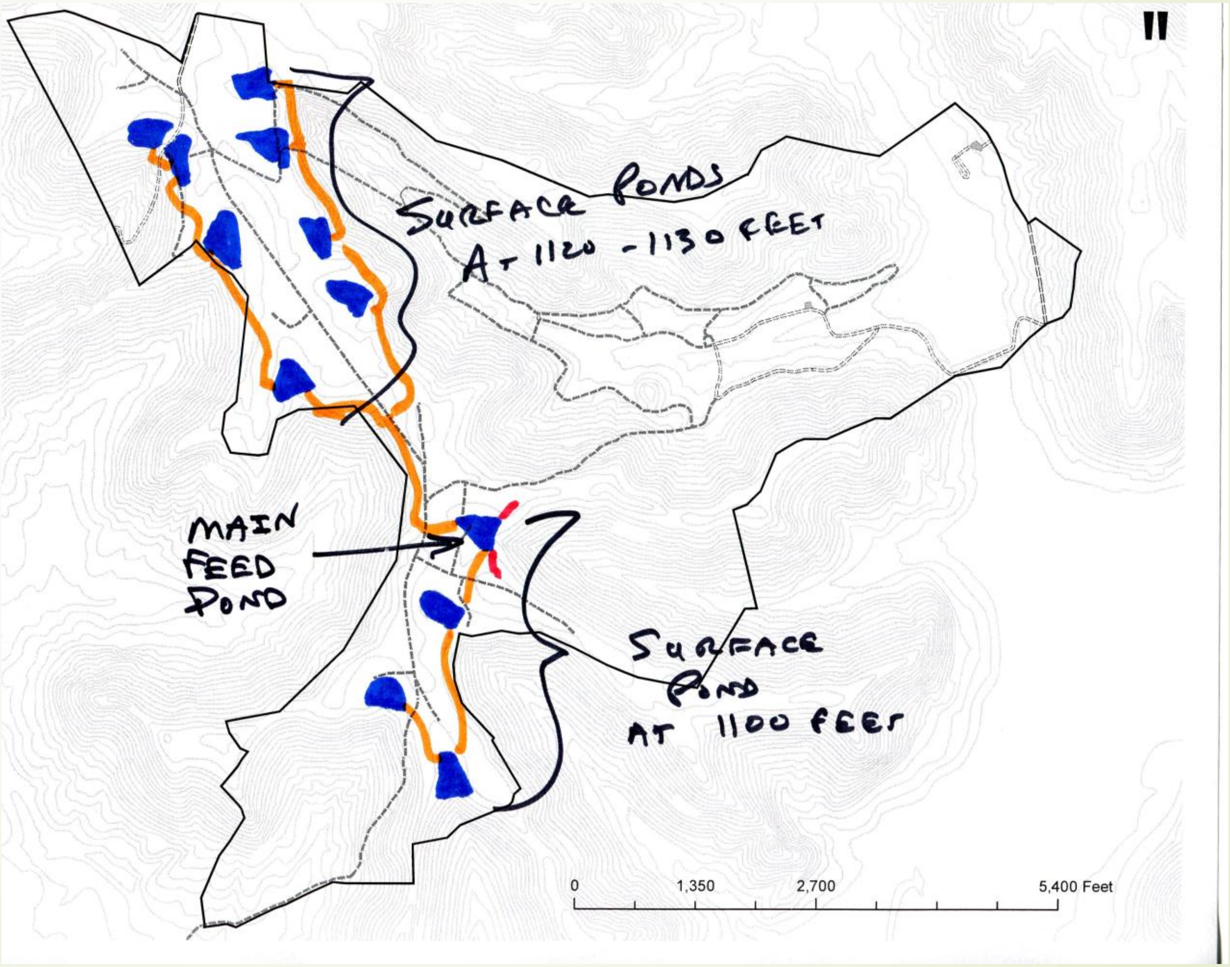
Additional geological attribute – persistent high water table on ridge due to impermeable "Nancy" Sand Rock Layer augmenting water storage capacity



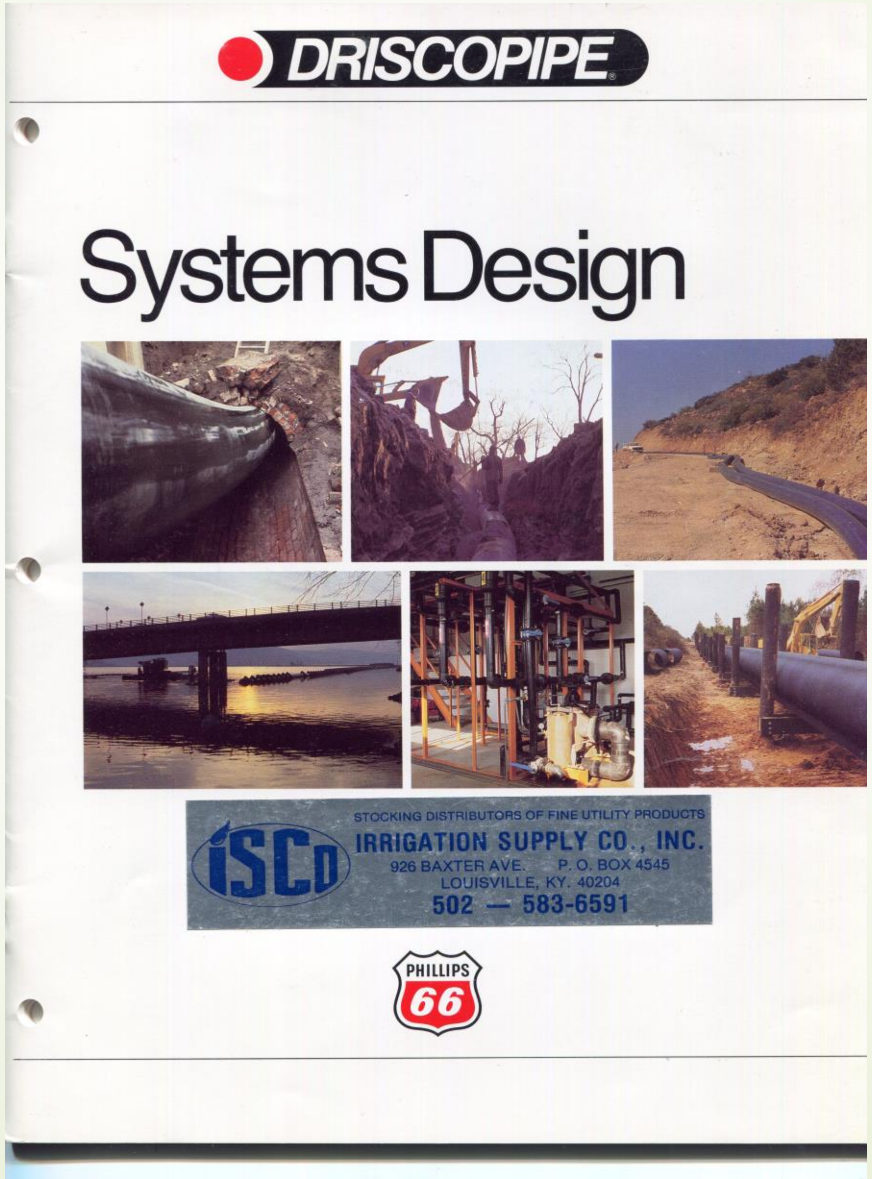
Collection System and Storage System: Pond map -112 Acre Feet capacity – 40% runoff capture



Pond water sharing system and flow to main feed pond



Connecting Ponds - PEC Pipe



PEC (Polyethylene Chloride) Special Characteristics

- Toughness
- UV Light Breakdown Resistance
- Durability
- Tolerates contents expanding – 1.1 expansion factor (water less)
- Agricultural use - burying just at surface
- Tolerates High Pressures
- Flow resistance loss to water very tolerable
- Cost – Oil Product so Fluctuates with Oil Prices
- Field Fabrication easy – Welding Process
- Reusable
- Long lifetime

PEC Pipe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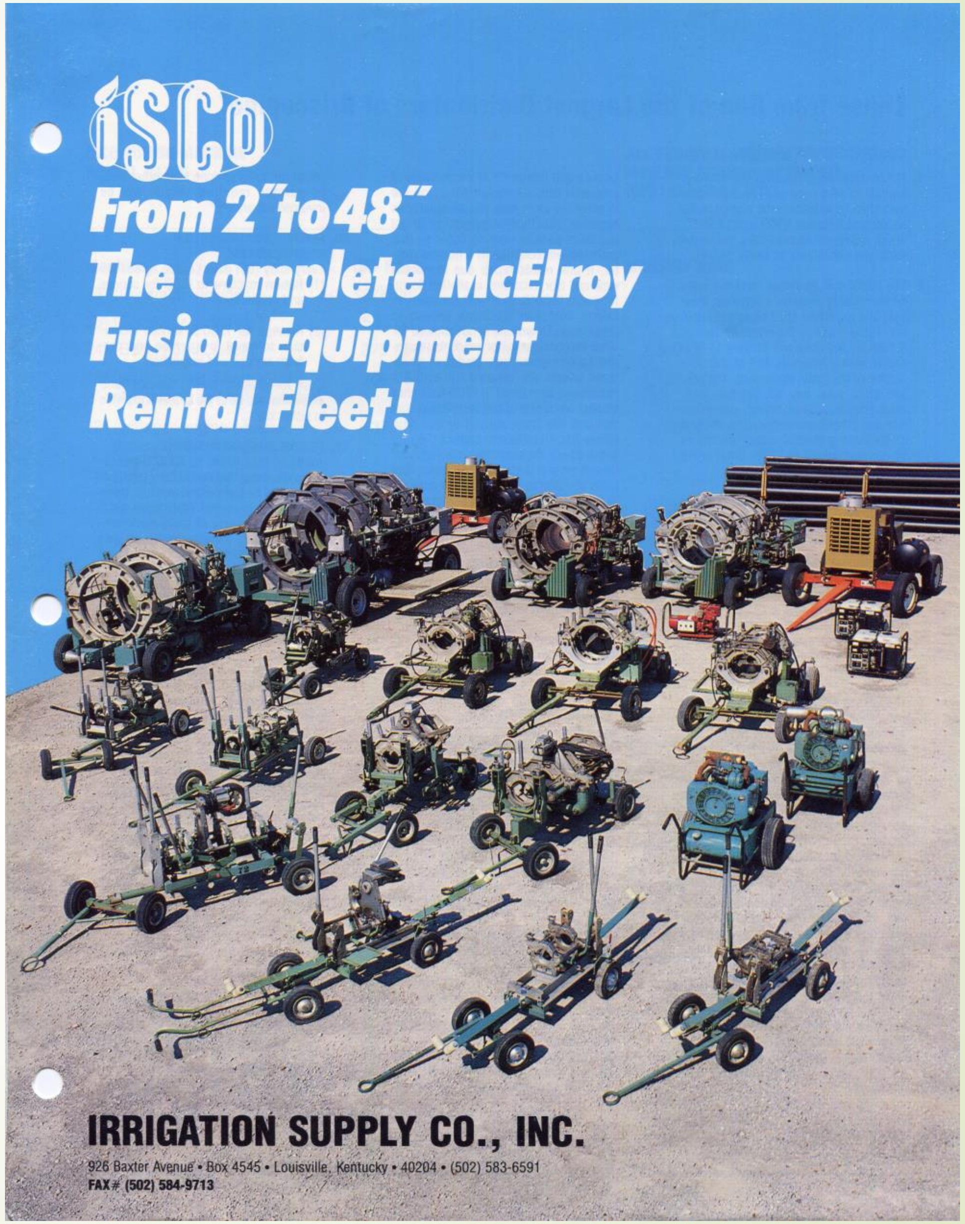
PEC Welding



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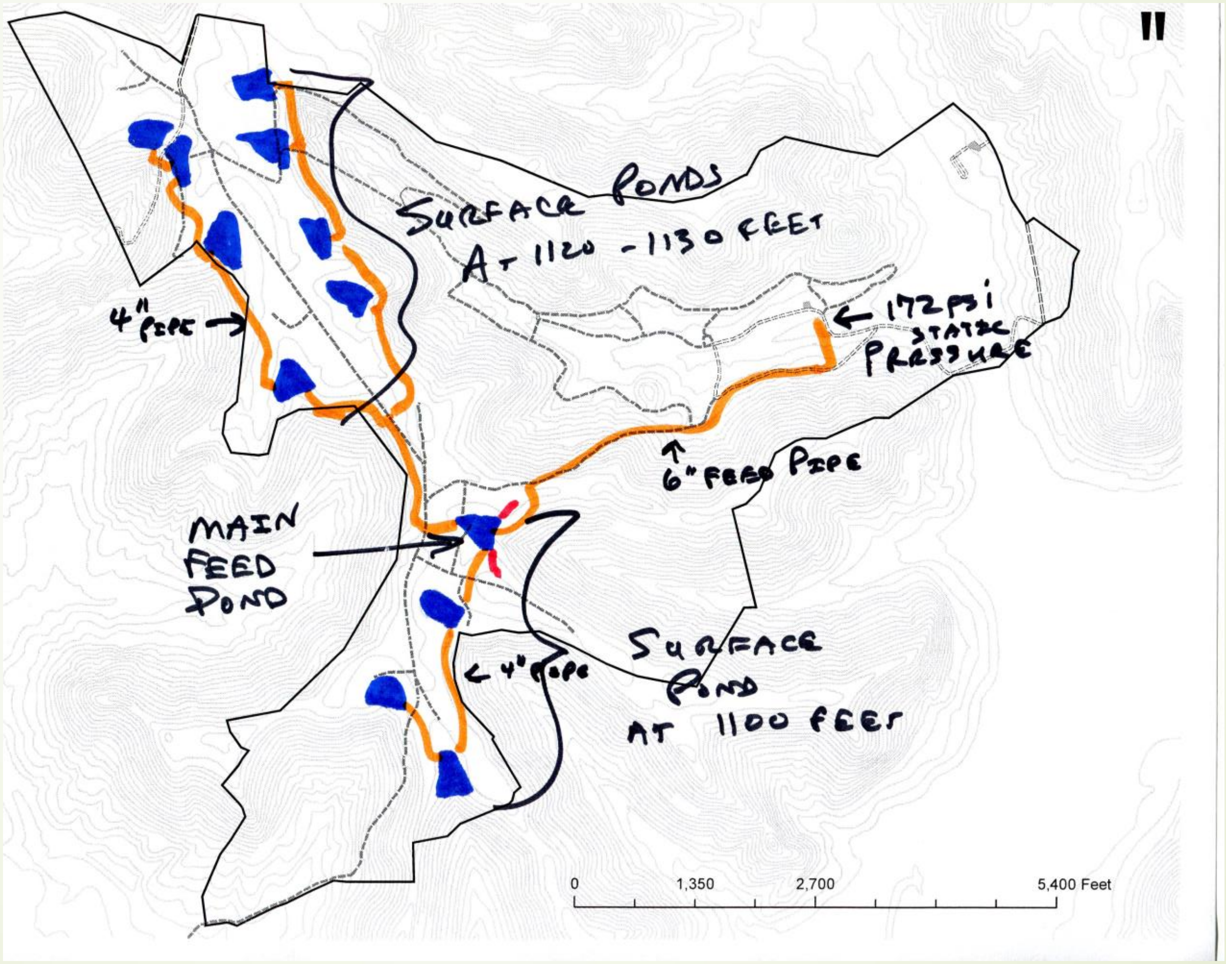
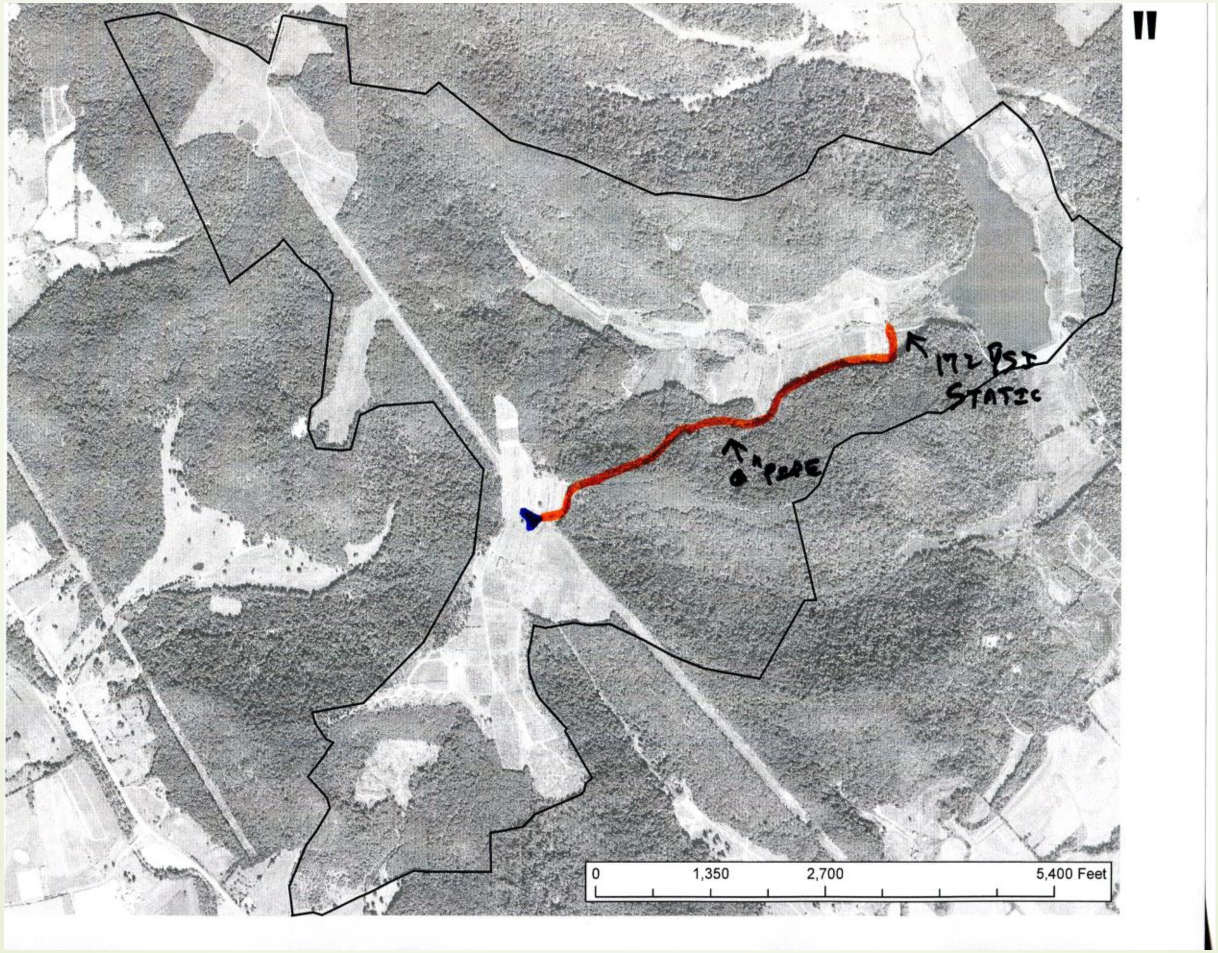
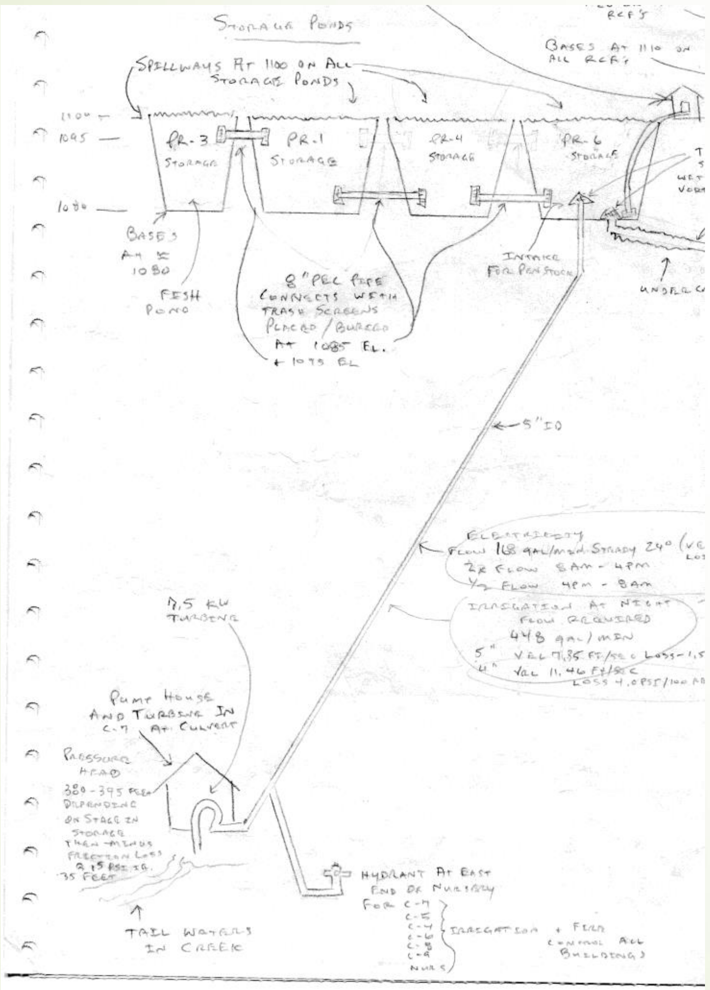
Feed Pipe to valley - also PEC pipe

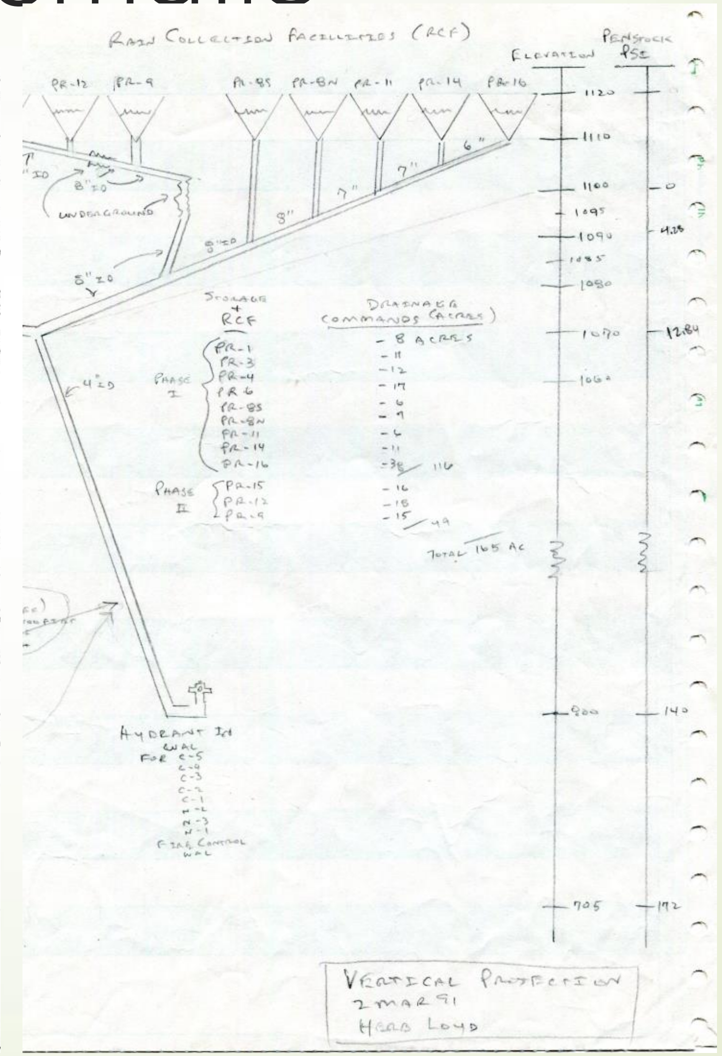


Switch to Aerial Map Depiction



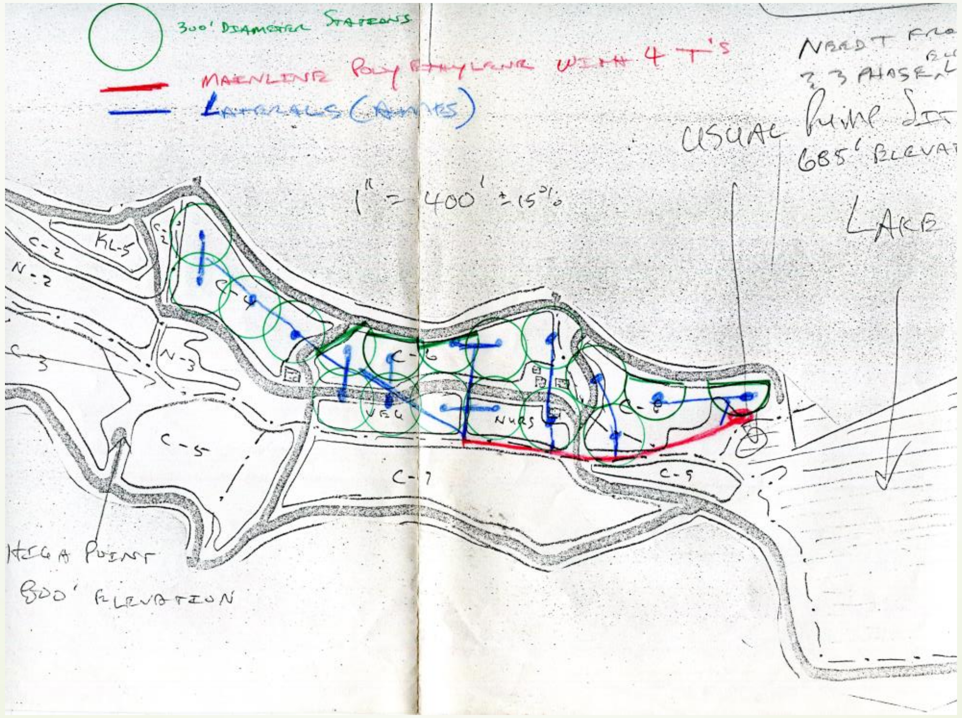
Feed System and Pressure Head (172 psi static) Schematic





Zoom in on valley

Irrigation Area Map for Growing Christmas Trees and Nursery Plants – 80 Acres



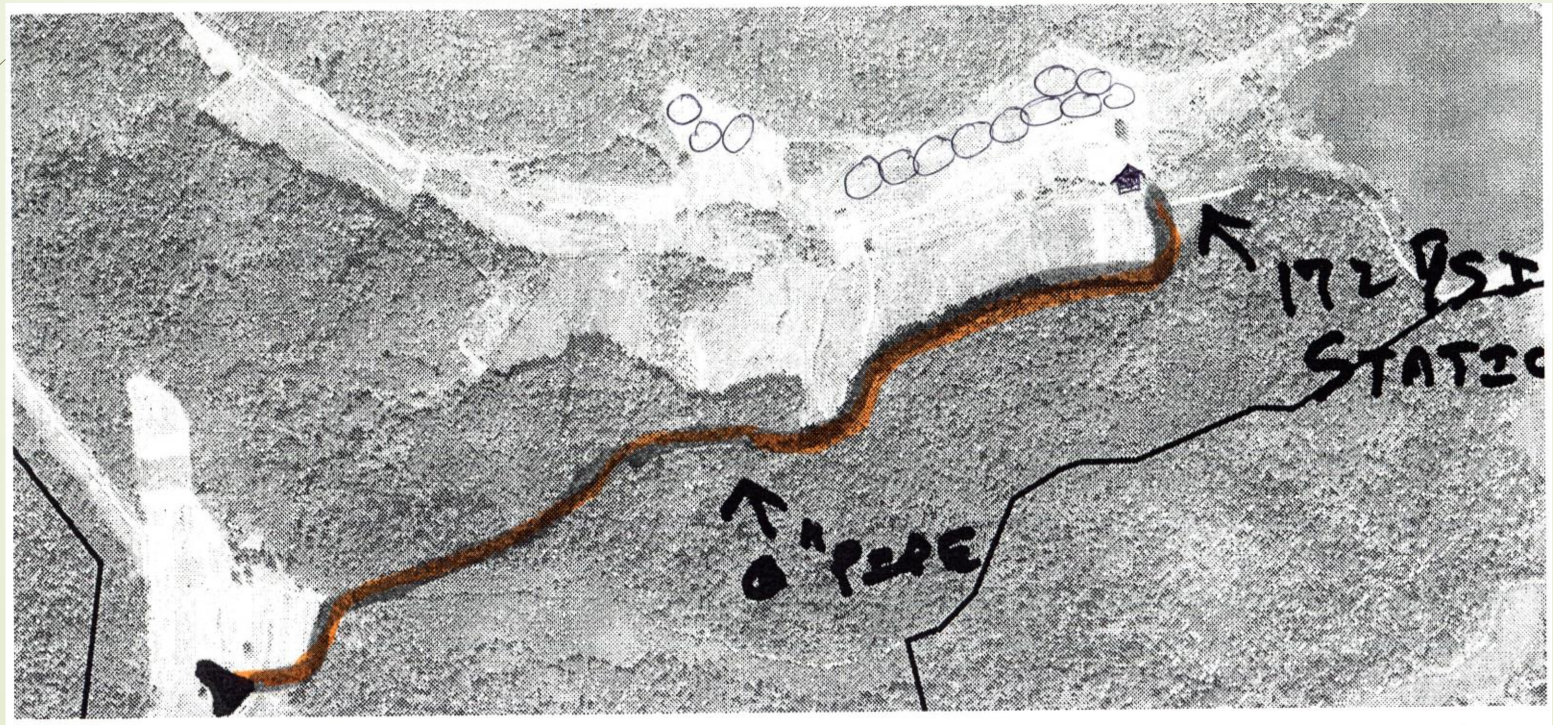
Financial Justification

- Christmas trees have 7-9 year rotation
- Irrigation allows
  - better seedling survival,
  - improves plant health,
  - reduces rotation time (one year in my calculations)

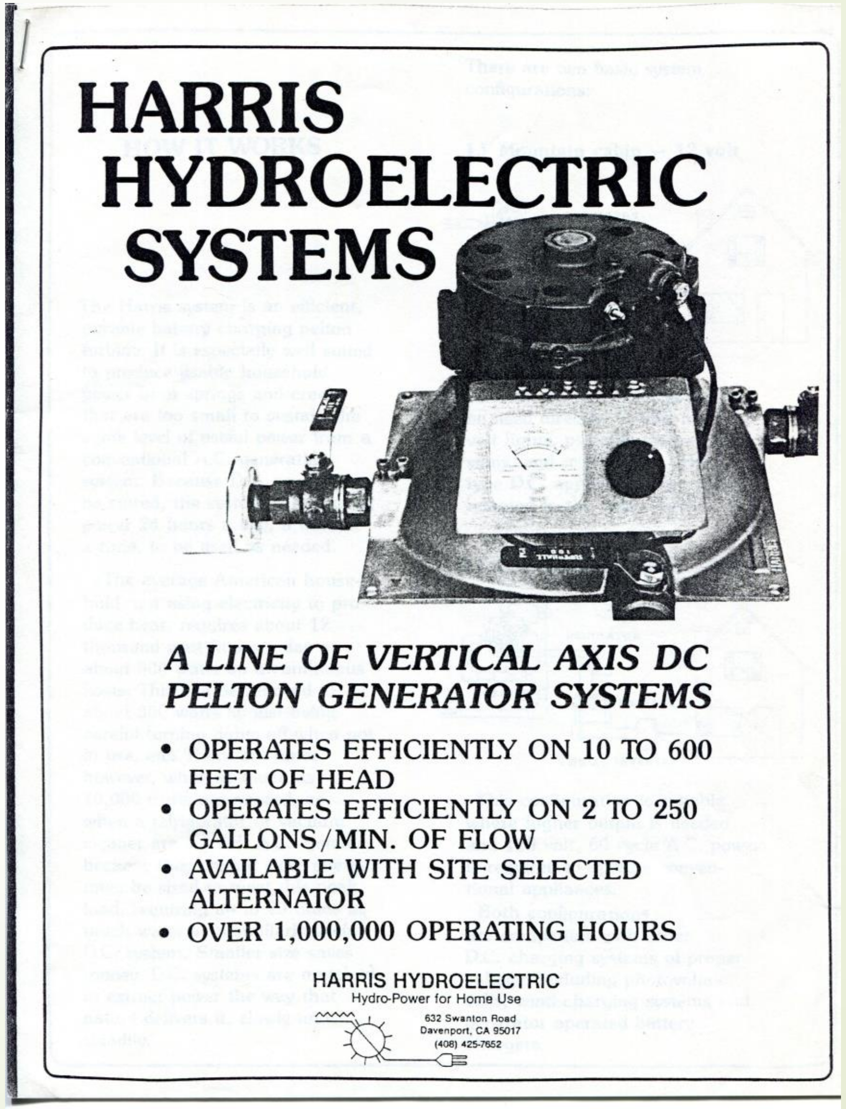
Alternative Uses Add on

- 10% of collected water needed for irrigation for Christmas Tree and Nursery Products – varies for other agricultural products
- 90% left in Hutton and Loyd case for alternative Uses

Hydroelectric – Aerial Photo with turbine/generator house at 700 feet elevation – 172 psi pressure head



Small scale hydroelectric system are available


HARRIS HYDROELECTRIC SYSTEMS

A LINE OF VERTICAL AXIS DC PELTON GENERATOR SYSTEMS

- OPERATES EFFICIENTLY ON 10 TO 600 FEET OF HEAD
- OPERATES EFFICIENTLY ON 2 TO 250 GALLONS/MIN. OF FLOW
- AVAILABLE WITH SITE SELECTED ALTERNATOR
- OVER 1,000,000 OPERATING HOURS

HARRIS HYDROELECTRIC
Hydro-Power for Home Use
632 Swanton Road
Davenport, CA 95017
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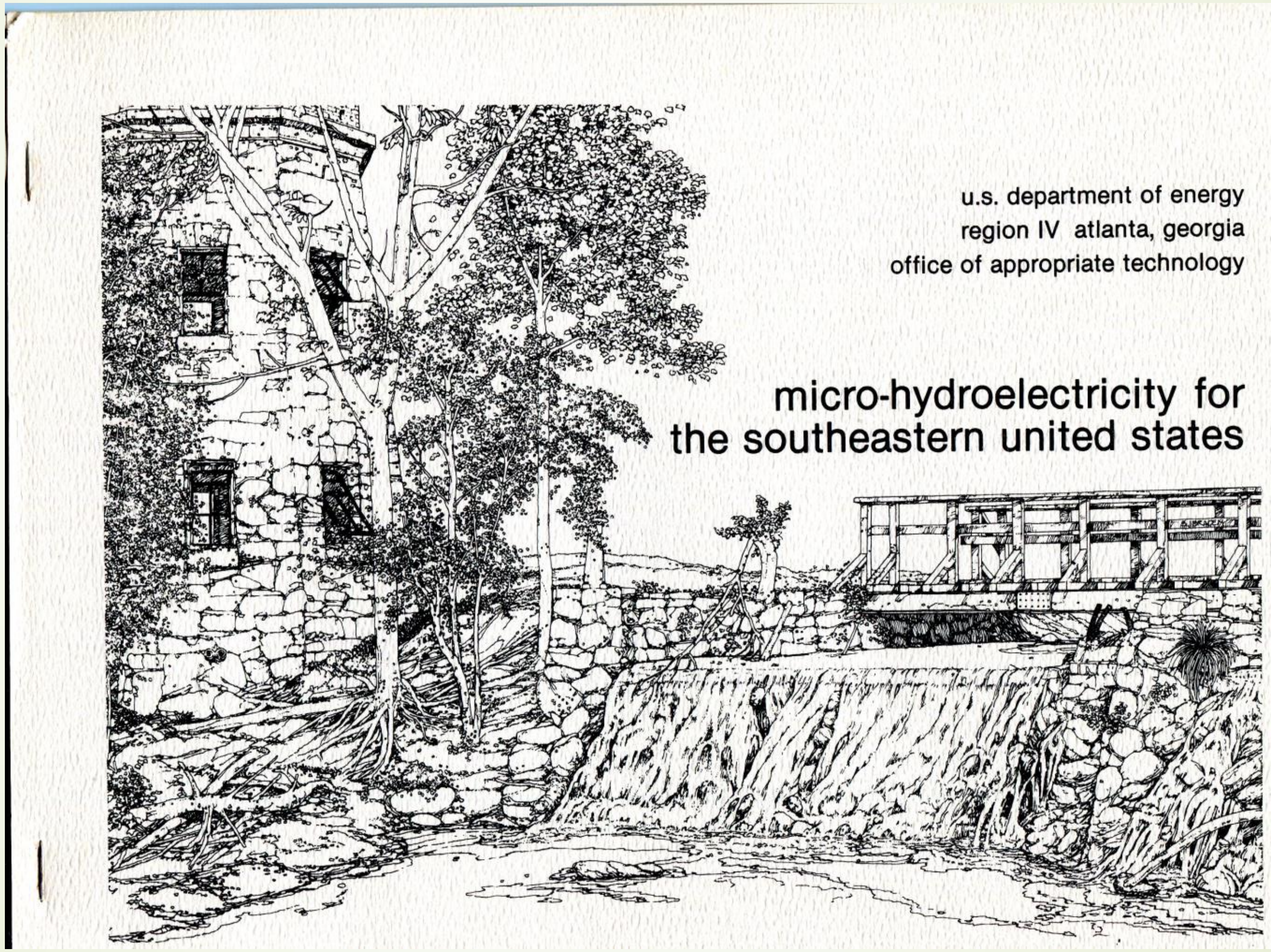
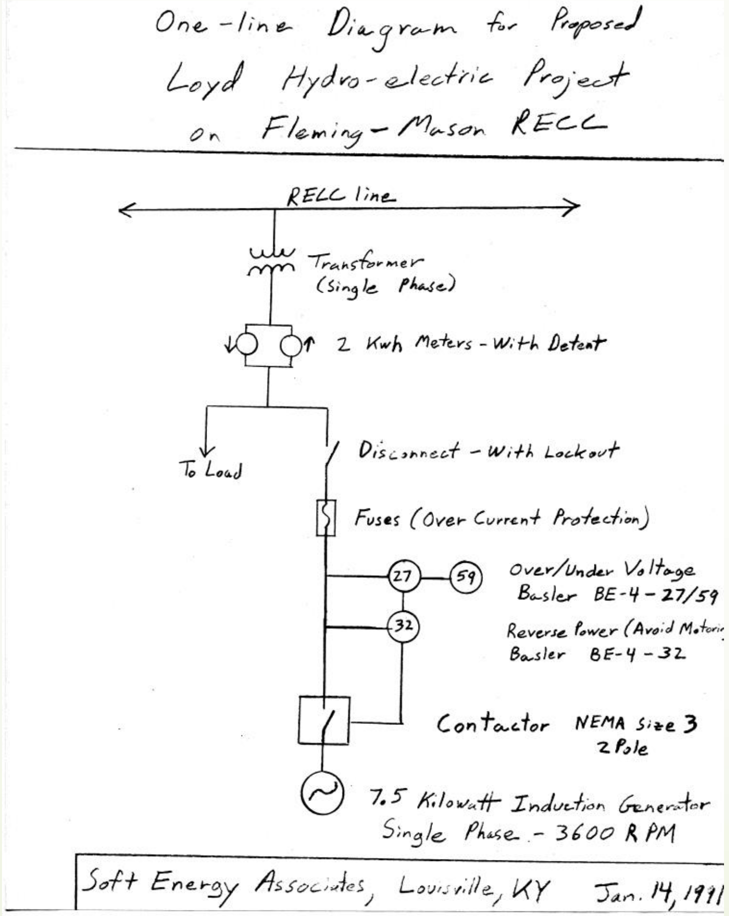
U.S. DOE Manual



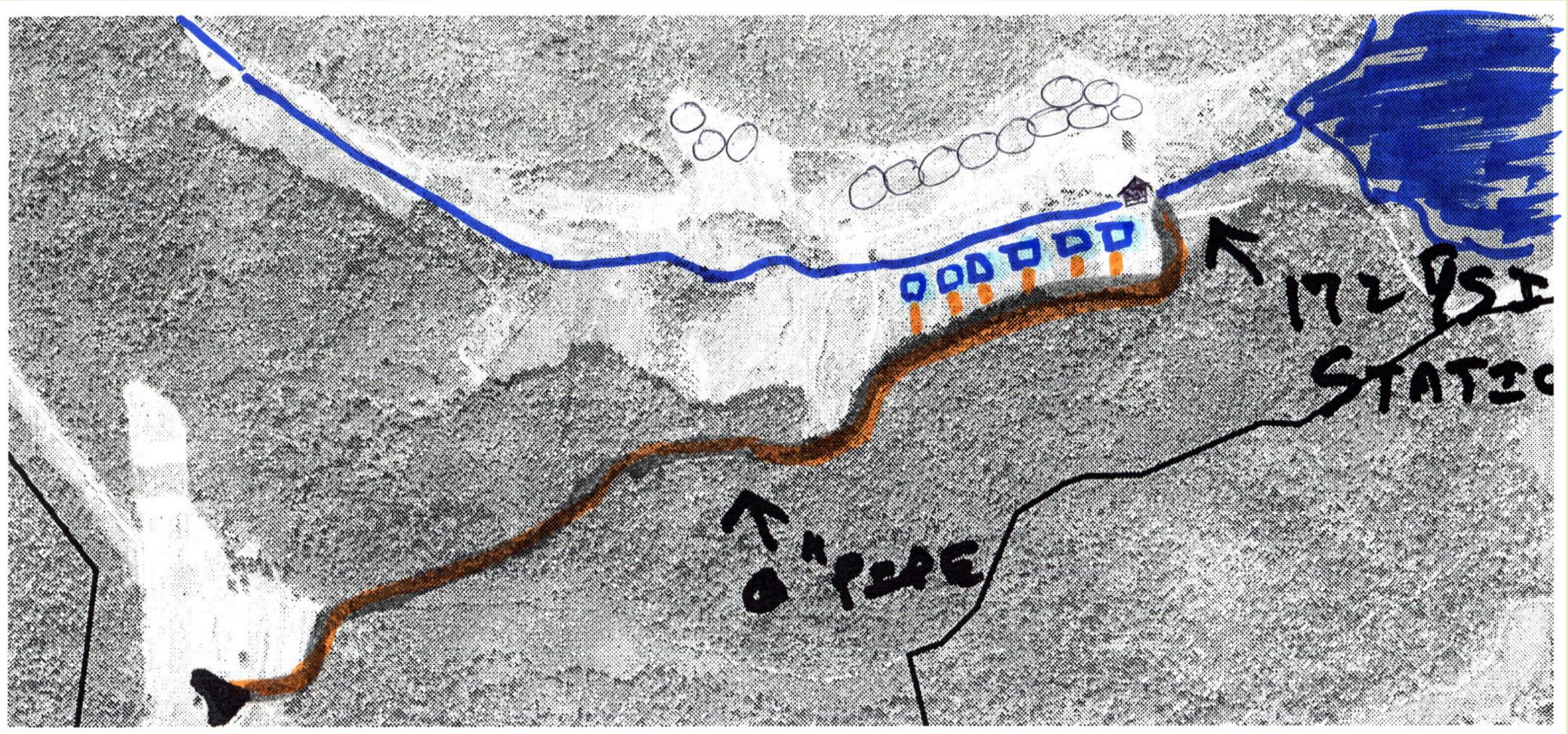
Hydroelectric (High Pressure Small Scale)

- 7 kilowatt steady
- 20 kilowatt triple flow
- Farm needed 16,200 KW/Hours per year
- Calculations showed could produce 48,000 + kilowatt hours per year
- ? Sell excess to RECC – laws
- ? Use excess to convert gasoline machinery to battery powered machinery and charge from system

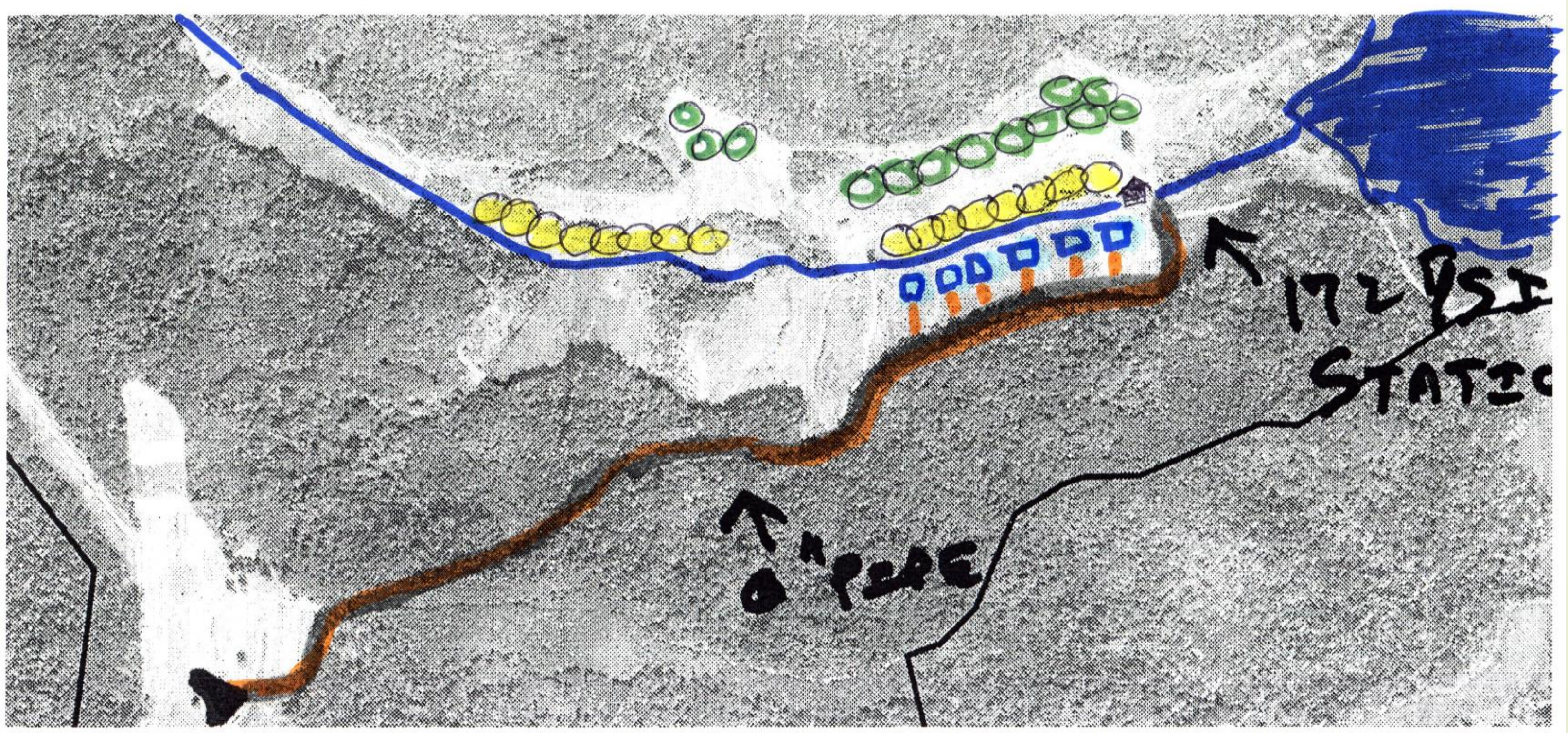
RECC Electric Grid Connect Schematic



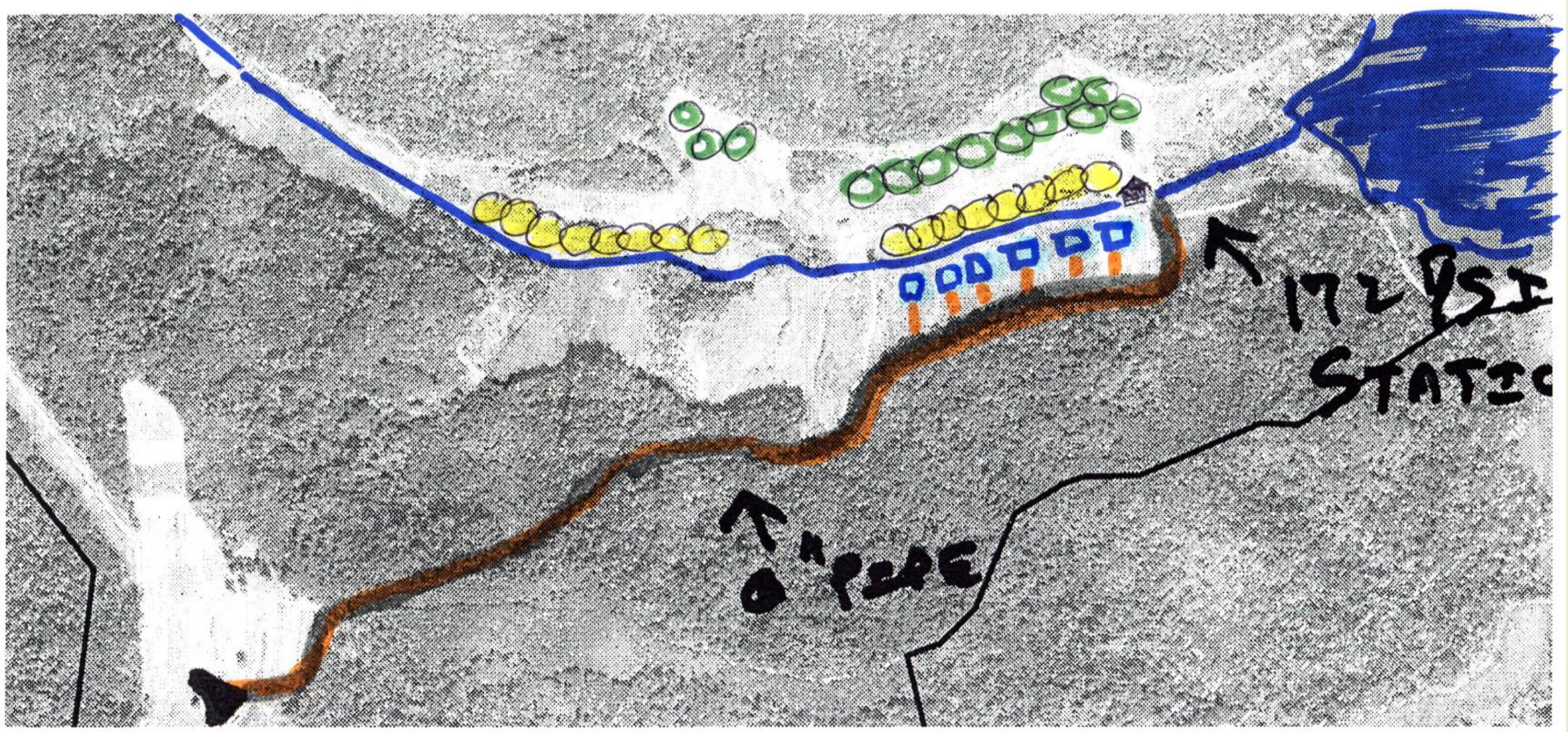
Aquaculture – Ponds schematic



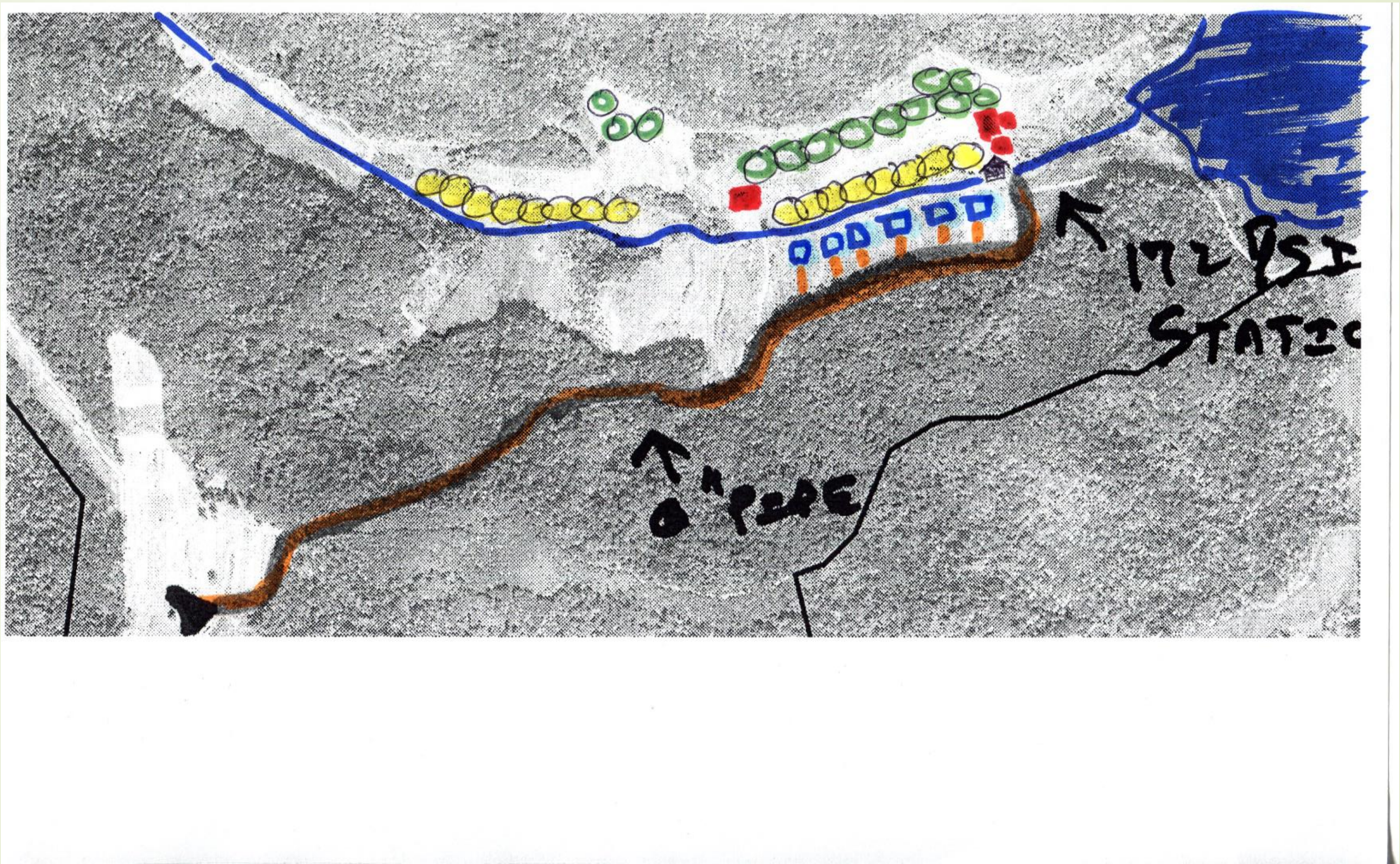
Vegetable Crops – rationale for late summer water to finish field grown vegetables – California comparison



Hydroponics – annual use instead of seasonal use for growing vegetables



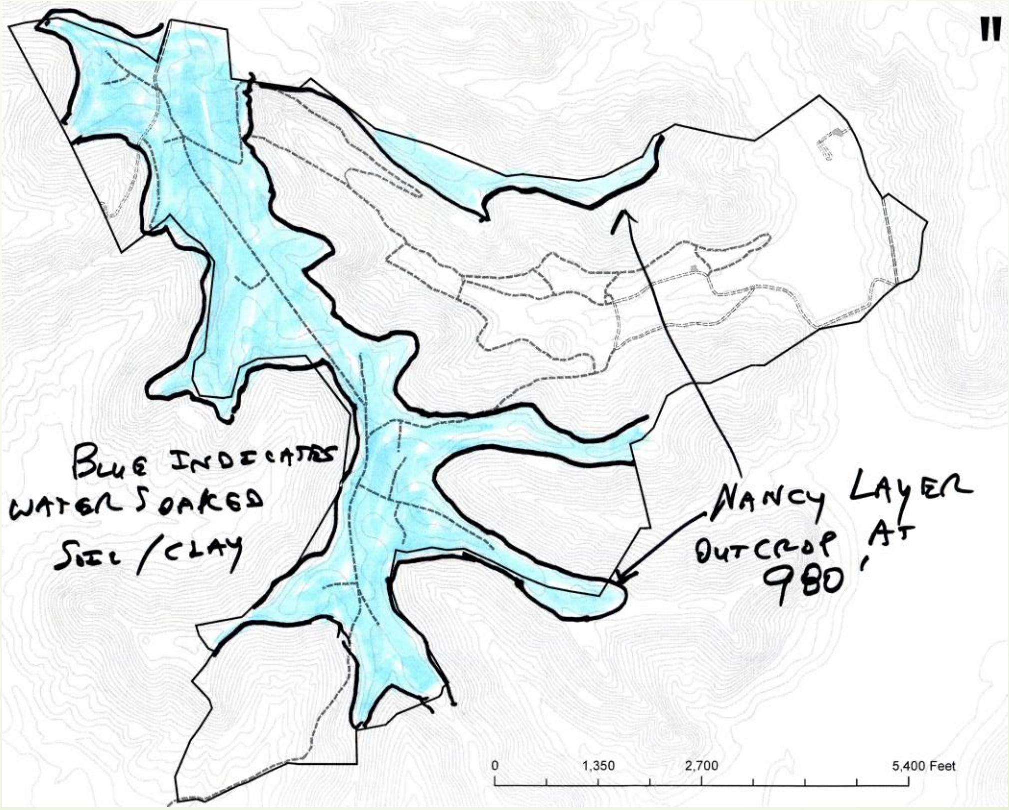
Hydrants in system for fire fighting and fire suppression



Miscellaneous

- Machinery
  - High pressure wash water for Vehicles
  - Convert tools from gasoline motors to battery powered
- Water Availability (Non-potable)
- Drought Mitigation

Additional geological attribute – persistent high water table on ridge due to impermeable "Nancy" Sand Rock Layer augmenting water storage capacity



Experts for Proof of Concept

- Kentucky Geologist
- Hydrologist
- Engineer for pond Design
- Piping and Flow Expert Engineer
- PEC Systems Design Engineer
- Integrated Systems and Trade Offs Calculations
- Irrigation Design Engineer
- Small Scale Hydroelectric Engineer
- Agricultural Cooperatives Expert - (Water Cooperative)
- Environmental Impact Expert (Plume below Ponds) (Water redistribution)

Summary:

- In final analysis really becomes a Farm/Agricultural/Homestead Water Management System
- Not just an irrigation system
- Area/Region wide implementation becomes an infrastructure just like the electric grid

- Questions?