

The following is an excerpt from a 30 page paper prepared by Jo-Ann Ford, a student at Yale and resident of Candlewood Isle at the time of its authoring in 1976. This paper has something for everyone who may be interested in the history, ecology, geology, or chemistry of Candlewood Lake and its surrounding towns.

The paper is richly annotated with sources and bibliographies for those wanting to perform further research on this subject. Its ecological warnings and remedies are even more germane today since there has been continued development of both the lake and its surrounding watershed.

Please request the full text of the paper at the library counter if you are interested in reading the entire paper.

CANDLEWOOD LAKE  
A view of its Future Based on Its History and Development

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This man-made lake so wide so Blue,  
Rests an eighth wonder of the world,  
Expanse of beauty unexcelled,  
Beneath the smile of Heaven unfurled,  
Here Yankee genius, Yankee grit,  
Have altered nature by machine,  
Here Yankee effort merits well  
The eulogy of a LaMartine.  
Technicians here have hugely wrought  
With high success, with skill untold:  
Thanks to their art the land has seen  
Its value raised a hundred fold.

These lines of lofty praise are the translation of three verses of a poem written by Gregoire Margulis, a French author and scholar to extol the beauties and wonders of Candlewood Lake after his first visit 1949. The lake nestled in the western highlands of Connecticut was then only twenty years old, but had already been described by Karl K. Kitchen, the New York journalist who prided himself with having visited almost all of the famous lakes in the world, as one of the five or six most beautiful lakes in the world.

The creation of Candlewood Lake, which took place in 1928, was the spin-off benefit of the master plan of the Connecticut Light and Power Company to build the Rocky River power plant in New Milford and develop the hydroelectric potentials of the Housatonic River. A predecessor company, the Housatonic Power company, had already pioneered in the field by building a power plant in 1904 at Bull's Bridge, approximately

6.3 miles north of the juncture of the Rocky and Housatonic Rivers, and demonstrated the feasibility of sending high tension current for greater distances than had previously been considered economical. By 1907 title was acquired to the site where the dam which creates Candlewood Lake is presently located, and the Connecticut Legislature granted authority to proceed with a power development project.

The Rocky River was a meandering Housatonic tributary, draining ponds in the south and traveling north in and out of rocky ridges, passing through the village of Jerusalem which now no longer exists, to join the Housatonic River north of the center of New Milford. Even in colonial days the Rocky River's sudden drop of about 200 feet was recognized as an important resource, and it was harnessed to furnish power for several mills. However, those establishments were no longer in operation in this century, and only the rusted machinery and parts of the wooden wheel of one small mill remained in 1926.

Although the Bull's Bridge plant started operating in by 1904, engineering plans for further development remained in the planning stage for a number of years. It was not until 1917 that more decisive action took place. At that time, an enterprising lawyer named J. Henry Roraback began buying potential dam sites along the Housatonic and Connecticut Rivers. In the same year, he also purchased the stock of the Housatonic Power Company and eventually named his combined enterprise the Connecticut Light and Power Co. As president of the company, he had the foresight to see that the economic growth of the area would be increasingly dependent on electric power. By 1919 his utility company completed construction of the Stevenson Dam just above Derby on the Housatonic River and 25 miles below the Rocky River. Then attention was focused on the final formulation of the plan to create a pumped water storage reservoir in the Rocky River basin and build a generating station in New Milford. A facility at Shepaug, 14 miles below Rocky River, was also on the schedule and was completed in 1955.

To flood the Rocky River basin and the four existing ponds, Squantz, Barse, Crick and Neversink, a total area of 5,420 acres had to be prepared. Farms and other homes, schools and churches, including two small cemeteries sparsely settled the countryside. New Fairfield and Sherman were two of the farming communities where people were forced to sell their land and leave their homes. In 1925 Charles L. Campbell began buying large tracts of property in this area which he deeded to the Power Company. It is no surprise that several families refused to sell their land. Since the Power Company had the authority to flood the valley, some property inundated by the lake is still privately owned.

In the clearing operation, at least 100 buildings of various sorts were demolished or moved, and all of the graves were relocated. The "Yankee grit" mentioned in the opening poem came from crews of hundreds of Maine and Canadian woodsmen and local lumbermen who worked for months, without the use of power tools, chopping down countless acres of timber and brush below the 440-foot contour line. Construction of the main dam and power plant in New Milford and the four smaller dikes to build up the low points in the rim of the basin began in the summer of 1926 under the direction of the U. G. I. Contracting Company of Philadelphia. A well outfitted construction camp with quarters for about 600 men was set up near the proposed dam site and four smaller camps were situated throughout the basin. This temporary labor village even had facetiously name streets and was locally known as UGI-ville, a name without attractive connotations! In 17 months time, a work force of up to 1,000 men completed the entire job at a total cost of \$5,000,000, a bargain price even in the currency of the 1920's.

The main dam was built on the Rocky River above its confluence with the Housatonic River. It has a concrete base extending five feet below and ten feet above the original ground level, and above the concrete base a huge timber core wall was packed with 367,300 cubic feet of earth. The completed dam is 952 feet long, about 700 feet wide at its base, and 100 feet high at its highest point, which is 442 feet above sea level. Nearby a headrace canal was dug 3,190 feet long and 20 feet wide to serve as the route for water to enter the intake structure of the penstock. This penstock, over 13 feet in diameter, runs along the downhill contour for more than 1,000 feet to the powerhouse on the west bank of the Housatonic. The diversion tunnel through which the Rocky River flowed while the project was in progress was closed on January 7, 1928, and the pumping of Housatonic River water up through the penstock started on February 25, 1928. By

the end of December 1928, the water level reached an elevation of 429 feet above sea level, and the Rocky River hydroelectric plant went into operation.

As it is needed, water plunges down more than 200 feet through the penstock to the turbine. To carry water into the basin from the river, two 8,100 horsepower pumps are capable of hurtling one million gallons of water every four minutes a height of over 200 feet through the same penstock. This may not seem like an awesome capacity nowadays, but at the time of their installation these were the largest pumps of their type ever built in this country. There is an unconfirmed story that the pumps were so huge that the manufacturer questioned whether a decimal point had been misplaced in the specifications. When operated in reverse the pumps act as generators, and their capacity, when combined with the plant's main 25,000 kilowatt generator, gives Rocky River a total yield of 32,000 kilowatts.

When this unique power plant went into operation in 1928, it was alleged to be the only plant of its kind outside of Switzerland, and it retained the distinction of being the first pumped storage generating station of significant size in the United States for over 20 years. Although the economy of pumping water uphill to the reservoir to capture power from its downhill flow may seem to defy the laws of physics, that is not the case in this instance. The available water supply permits the plant to increase its generation of electricity during daily peak-load hours, and pump a return supply into the lake from the river during low-demand, night-time hours by inexpensive surplus power from its other plants. In addition, the Rocky River plant helps to regulate the flow of the Housatonic so that downstream plants at Shepaug and Stevenson can operate efficiently. The company claims the system actually increases the generating capacity of all three plants, and gives this example: For every 100 kilowatt-hours of electricity required to pump water into the, 67 are recovered when the same water is used to generate electricity at Rocky River, 30 are recovered at Shepaug, and 21 at Stevenson, for a total of 118 kilowatt-hours generated for every 100 used.

The new power plant was a boon to the area, but for many people its pumped storage reservoir was of more direct personal interest. The Rocky River had vanished, and in its place was spread a beautiful body of water covering eight and one-third square miles with a depth of 85 feet maximum and an average depth of 29.3 feet, and a total volume of 7,500 million cubic feet. Sixty-one miles of shoreline along fringes of hills with numerous coves and islands form what is now known as Candlewood Lake.

Four towns, Brookfield, New Fairfield, New Milford and Sherman, and the city of Danbury, with about half the lake falling in New Fairfield border the lake. In its initial period, the lake was called many names depending on the town in which one resided. Danbury was a leading contender, but New Milford was the first to use the name Candlewood because the lake water on the way to the powerhouse drops down within the shadow of Candlewood Mountain. The mountain, north of the lake, was so named by the early settlers in the region who learned from the Indians how to make Indian candles. These were made by splitting the pitchy heart of dry pine logs into narrow 8-inch strips, which burn like torches and could be used in place of wax candles. These strips were known as candle wood. The best pine wood for burning was plentiful on the mountain, and accordingly the mountain was given the name Candlewood. Although the name was adopted for the lake to avoid giving preference to the name of one of the adjoining towns, the name is most appropriate because the lake now helps to generate electric light measurable in millions of candlepower.

It is estimated that 40 square miles of watershed and natural rainfall supply the lake with approximately 2,930 million cubic feet of water, and an average amount of 1,400 million cubic feet is pumped in from the Housatonic River, for a total annual input of 4,330 million cubic feet. Each year evaporation accounts for the loss of about 590 million cubic feet, and 2,770 million cubic feet are utilized for power generation, a total output of 3,360 million cubic feet. On the basis of these calculations, it is estimated that the lake has a leak equivalent to 970 million cubic feet, or about 12% of its volume.

The sizeable discrepancy in the figures may be accounted for by errors in measurement of the watershed area, but it is quite likely to be due to a leaky lake and/or watershed. Geological peculiarities of the complex bedrock tend to support this possibility.

The bedrock which gives the Western Highlands attractive elevations and slopes is a complex structure with a high degree of metamorphism. The Berkshire, Housatonic and Hudson Highlands in Connecticut and the adjoining states have a basement complex of Precambrian gneisses, and similar rock structures form a smaller area in New Milford and Sherman. The northwest side of the Housatonic Highlands and the south side of the Hudson Highlands are bounded by high-angled reverse faults, and such faults are very likely to be present in similar rock formations in the lake area. To the south and east, the granite and hornblende gneiss of the Precambrian Highlands overthrust onto the multi-layered metasediments of another rock formation, which is not as steep as the Highlands. This second structural unit is widely intruded by younger granite, and different augen granite is intrusive into the Precambrian Highlands. This augen granite forms hills and accounts for the high relief just beyond the western shore of Candlewood Lake. Wide outcrops with 50-foot cliffs facing the lake are common, and piles of huge rocks that have been broken off from the cooling joints of these cliffs by weathering have collected at the base of many of the slopes. To the east, the principle ridge maker is the younger granite, and here, too, there are very steep, often vertical cliffs up to 50 feet high. The geological complexities of the bedrock with its structural discordances in the lake area indicate that there are likely to be many substantial clefts due to reverse faults, and these might account for the leakage of water.

It is also possible that the high-calcium limestone stratum under the valley of the nearby Still River extends beneath the lake. Before it became uneconomic, an exposure of limestone provided the area with an active industry.

Dolomitic rock was calcined in limekilns for the production of plaster. Danbury's Limekiln Brook and Brookfield's Limekiln Brook are the present day reminders of this activity. Inwood Marble, almost pure  $\text{CaCO}_3$ , was also quarried in the nearby area, and crushed on the premises to be sold for agricultural lime. This is further evidence that there are generous deposits of these porous minerals in the lake vicinity. Such a porous layer plus rock deformations and the reverse faults may be the reasons for the leakage of significant quantities of water from the lake and its watershed.

As an interesting bit of additional information indicating that the lake area is prone to leakage, I would like to point out that Squantz Pond, which is natural in origin and is now separated from Candlewood Lake by a causeway, may at one time have been much larger than it is now. The pond received its name from Squantz who was chief of the Scatacook Indians living in this locality in the 18th century. Some years ago, the remains of a very large Indian canoe, 22 feet long and 5.5 feet wide, were raised from the bottom of Squantz Pond. The unusually large size of this canoe indicates the possibility that 200 or more years ago this body of water may have been considerably larger than it is today.

Once established, the Rocky River power project became a double-barrelled success. Not only did it expand the hydroelectric power capacity in the Housatonic region, but also Candlewood Lake became a scenic attraction which enhanced the five surrounding communities and influenced the growth and prosperity. The lake was stocked with fish, and in keeping with the company's policy, land was made available for recreational use. Town parks and beaches were developed by each of the five communities, and added attractions for public use are the Squantz Pond State Park and Pocatuck State Forest, which front on the lake in New Fairfield.

In the immediately succeeding decades, land values soared as the lakeshore became studded with resort colonies containing summer homes and many substantial year-round dwellings. The houses were attractively designed and spaced without sacrificing the sweeping beauty of the natural landscape. The rugged topography also provides its own built-in protection by inhibiting real estate development, as will be later proved by soil analysis. However, available areas in the hilly backdrop of the lakefront were heavily developed by the 1950's. By this time, as shown on the attached map, there were dozens of lake colonies of varying size, the larger ones containing hundreds of homes. Most of these are self-reliant for such services as road maintenance, snow removal and garbage collection, and provide varied recreational activities at beachfront clubs. Water supply comes from private wells although a few homes have filtering systems so

lake water can be used. Waste disposal is handled by individual septic systems. It is staggering to realize how the area is literally riddled by wells, and it is even more staggering in an environmental sense to contemplate the thousands of septic tanks in the ground.

In the early decades, the majority of the population in the lake colonies was seasonal inhabitants, and this also meant only seasonal use of septic systems. It is estimated by the 1950's more than 10,000 people swelled the local population in the summer, providing a considerable economic boost to the towns. The seasonal residents paid local property taxes and brought their purchasing power to the area without drawing heavily on town services for either educational, recreational or other needs. However, increasingly in recent years more and more year-round residents have been replacing seasonal occupants, and there has been marked growth in the general population as well.

A look at the growth in the stable population the five communities helps to illustrate the expanding growth: With the exception of Danbury, which was at the time the foremost hat making city in the country and was established as the trading center of the area, it can be noted that the populations of the other towns decreased from 1900 to 1930. Recalling that Candlewood Lake came into being just before 1930, this decade can be observed as the turning point, and for the following three decades there were gradual but substantial increases in the population of each town. It is also in this period that the influx of summer lake residents more than doubled the 1950 population of the area, without counting Danbury population. The decade from 1960 to 1970 exhibited the most dramatic increase in stable population with New Fairfield more than doubling its size and New Milford and Sherman approaching similar growth and Brookfield on its way to tripling its population. During this decade, Danbury increased about 25%, a percentage closer to the 20% increase for the entire state of Connecticut for this period.

In this decade of burgeoning growth and increase of year-round residents, it became necessary to ponder what effect these changes were having on the environmental well being of Candlewood Lake. Recreational use was becoming so significant that many newcomers were only vaguely aware of its primary purpose as a pumped storage reservoir for hydroelectric power. On busy weekends, as many as 3,500 to 4,000 boats, with powered boats in the large majority, used the lake, being serviced by seven marinas, which pump gasoline and oil from lakeside docks. Fortunately gas and oil skim on the surface of the water still seem to be fairly minimal. However, during the ten-year period from 1960-70, there was visible increase in algae growth in the lake. In earlier years, minor amounts of algae were observed in late August climaxing the warm summer months and active recreational use of the lake, but it started to appear earlier in the season in widely scattered sections of the lake.

In the natural balance of lake ecology, fish feed on the tiny plant algae and animal plankton. When the fish die and sink the bottom, micro-organisms reduce the remains into basic elements to be recycled as nutrients, consuming oxygen from the water in the process, and these nutrients begin to accumulate in the lower levels. In a thermally stratified lake such as Candlewood, there is no circulatory exchange between the warmer upper waters and the cooler lower waters in the summer. However, in the fall when the warmer water above the thermocline cools, and the water temperatures become uniform throughout the entire water column, the water of the whole lake can circulate and mix. Thorough mixing is assured before the lake freezes over in the winter because when the temperature of the surface water decreases to 4C., the densest temperature for water, the upper water will move downward, causing complete oxygenation of the lower depths. In the spring, there is similar mixing when the surface water again reaches 4C., and the two strata are at the same temperature, before resuming summer stratification. This is a beneficial process because the upper waters can oxygenate the deeper waters, which become oxygen deficient in the summer months. However, the basic elements released from sediment particles undergoing bacterial mineralization at the lake bottom will be carried up in the overturning water. The end products of bacterial mineralization are the nutrients, which promote algal growth the following summer. Then the plant plankton are nourished by these nutrients and produce replacement oxygen for the water. Animal plankton feed on plant plankton, and the

minute animals and plants again become food supply for fish. In this way, the cycle of teeming life processes in the water is balanced and perpetuated.

The delicate interrelationships of these organisms are readily disrupted when the water is oversupplied with nutrients. Algal growth is stimulated by the presence of nitrogen and phosphorus in ratios varying from 7/1 to 14/1. Massive algal production and die-offs seriously deplete the oxygen essential to fish life, and accelerate the aging, or dying, process of the lake called eutrophication. Although algae are not harmful to human life, they have an offensive appearance in addition to being associated with eutrophication.

By the late 1960's some alarmed authorities were predicting that in five to twenty years Candlewood Lake might be clogged with algae and face certain doom. There is little doubt that the increase of algae is the green warning signal of a pollution problem, but what is the solution? Although the power company owns the lake, it does not have control over its water. The company functions as a public utility, not a regulatory body, and jurisdiction over water quality is the responsibility of local and state officials. More or less periodic but rather haphazard testing for coliform count was being carried out by the various town and the Danbury News-Times during the summer months, but more comprehensive testing is indicated to determine the biological activity of the lake. When the lake is involved, the governmental structure encompasses the relationships of five communities, regional interests and a number of state and federal agencies. The orderly exchange of information about testing and other matters is cumbersome, but very important.

The difficulty of five localities, each with partial jurisdiction over the lake, to reach unanimous agreement on regulations became obvious in 1964. An ordinance to prohibit boats with on-board toilets was passed by the towns of Brookfield, New Fairfield, New Milford and Sherman, but Danbury altered the ordinance to allow boats with operable toilets if they had holding tanks in Danbury's part of the lake. The lack of uniformity in the regulation made it an unwieldy ordinance to enforce.

Fairly or not, many people were beginning to wonder if the cleanliness of the water was being taken for granted simply because there was no direct discharge of industrial pollutants into the lake, and others blamed the untreated water being pumped into the lake from the Housatonic River. On the other hand, more and more alert officials and citizens were becoming mindful that pollution is usually caused by various human activities close to home. The general concern about changes in the biological activity of the lake prompted a thorough analysis of the lake's plant nutrient budget conducted by the Connecticut Agricultural Experiment Station from August 1968 to July 1969.

Extensive sampling showed that the water leaving the lake for power generation contained fewer nutrients (mean concentration 0.017 parts per million phosphorus and 0.347 ppm. nitrogen) than the water in the Housatonic River (mean concentration 0.066 ppm. phosphorus and 0.550 ppm. nitrogen.) The budget data indicated that nutrient sources in the watershed slightly exceeded those in the water pumped into the lake from the Housatonic, and that the lake was retaining an estimated 68% of the phosphorus and 51% of the nitrogen entering from all sources. It was implied that the lake sediments were absorbing the incoming nutrients, and in this way helping to maintain low concentrations of phosphorus and nitrogen in the overlying waters. Calculations also verified that the short supply of phosphorus, rather than nitrogen, was the nutrient limiting the growth of algae.

In 1959, the State Board of Fisheries and Game listed Candlewood Lake as average in fertility and in the production of plankton and bottom fauna, but the 1969 nutrient budget was the first and remains the only one ever calculated for the lake. Therefore, it was not possible to determine if changes in fertility had occurred since its impoundment. Candlewood's 40-year record was noted as distinctly more favorable than two other impounded lakes in the Housatonic River basin. Lake Zoar, created in 1919 when the Stevenson dam was built, and Lake Lillinonah, created by the Shepaug dam in 1955, both became eutrophic shortly after impoundment. In my opinion, this is not surprising. Zoar and Lillinonah both continuously receive the flowing water of the Housatonic, and have an enormously larger nutrient input from this source. There is always a greater land-water interchange in moving water, and the fast movement of the river current retains suspended particles. When the flow is interrupted by the lakes, the particles, including nutrients, are

deposited as a feast for the algae. For instance, Zoar has an estimated annual nutrient load of 3,380 lbs. of nitrogen per acre of lake surface and 330 lbs. of phosphorus, and Candlewood luckily has only 24 lbs. Of nitrogen and 2 lbs. of phosphorus.

The good news of the 1969 nutrient budget was tempered with the warning that at some point not as yet scientifically predictable the capacity of the lake sediments to absorb the incoming nutrients might be exceeded. In other words, the sediments cannot be considered a permanent nutrient trap. In fact, the ability of the sediments on the bottom of the lake to hold excess nutrients has never been satisfactorily explained. However, the lake bottom has before caused things to happen that have never been well understood. For instance, in the fall of 1965, residents saw some startling examples of what lurks when large sections peeled away from the bottom and rose as floating islands. The masses of "sailing" muck were embedded with stumps and root systems left when the was cleared of trees in 1928. The biggest island was 300 feet long, and four other were about 100 feet long and 3 to 4 feet thick. This extraordinary occurrence may have been caused by decreases in water pressure due to an unusual lowering of the lake. Earlier that fall it was necessary for the power company to lower the lake approximately 7 to 8 feet in order to replace part of the penstock. Ordinarily the level of the lake does not fluctuate a great deal although it is always lower in the fall. The soggy islands were an upheaval no one had bargained for! There is still much that is unknown about sediment chemistry and reactions to changes in pressure.

In the summer of 1973, a graphic example illustrated how readily changes in land and water use can contaminate the lake. Over the strong objections of local residents, the State Board of Fisheries and Game in 1971 constructed a boat launching area for unlimited public use in Lattins Landing, a cove located in the Danbury area of the lake. The ramp is large enough for three cars to use at once, and there is a graded parking lot for 150 cars and boat trailers. In the summer of 1973, the coliform count shot up to 2,400 per 100 milliliters, and the cove had to be closed for swimming for most of the summer. Whenever the coliform count reaches 1,000/100ml., water is considered unsafe for swimming, and the count is usually much below 500/100ml. within swimming areas on the lake and less than 100/100ml. in open water. In the opinion of many of the residents, the launching site and parking area had changed the elevation and contours of the ground causing an increased runoff from septic systems, and local health officials also located 8 malfunctioning septic systems. In addition, the facility had been conceived without sufficient attention to the effect of increased traffic in the small cove with as many as 238 boats being launched on weekends. The interrelated causes of pollution in Lattins Landing were a true example of Barry Commoner's three laws of ecology: 1. Everything is connected with everything else. 2. Everything goes somewhere. 3. There is no such thing as a free lunch.

As the decade of the 1930's turned the corner from decreasing to increasing local population, so it might be said that th 1970's mark increased awareness and action for environmental protection. To insure the sound ecologic and environmental use, care and development of the lake, the Candlewood Lake Authority was formed early in 1972. The Authority is composed of three unsalaried representatives from each of he five communities and acts as the channel for local, state and federal agencies. One of its first accomplishments is the centrally located Sand Island Project, which serves as a communications center and sanitary facility for boaters and swimmers, as well as an area for public recreation. In addition to maintaining safety on the lake through police patrol, the Authority conducts a continuous program of water testing to monitor coliform counts in all area of the lake. In 1974 it alerted all lakeshore dwellers to the hazards of defective septic systems, and urged their cooperation for the preservation of water quality.

The most immediate success of this fledgling agency is its authoritative presence on the lake not just as the keeper of law and order, but as a spur to prod public awareness of pollution problems and the necessary safeguards. Although the naked eye is not a very accurate testing device, the lake appears visually cleaner and freer of algae growth in recent summers than it did in the late 1960's. Hopefully a more scientific appraisal will come from the proposal of the Environmental Sciences Department of Western Connecticut

State College to undertake a study of the physical, chemical and biological properties of the lake during 1976. This will be excellent research training for its students and a valuable service to the communities. The Sand Island Project is also a testing ground for future recreation centers on the lake, and for this reason it is being observed by the power company. The Federal Power Commission encourages companies to provide access for recreation on their impoundments. In connection with its application to the Federal Power Commission, the power company submitted in 1970 a plan for 13 new recreation sites on the lake, but the U. S. Bureau of Outdoor Recreation favored implementation of a state plan to accommodate 15,000 swimmers, campsites for 400, picnic areas for 500 and boat launching ramps in each town, to make the lake accessible to residents of New York, Waterbury, Harford, New Haven and other cities. Public uproar from area residents caused these extensive plans to be dropped in 1972, but it is still recognized that some increase in recreational facilities should be planned in a logical manner.

Both the Candlewood Lake Authority and the Housatonic Valley Council of Elected Officials are giving consideration to the lake as a possible future source of potable water. In 1972, the Authority in collaboration with Danbury officials attempted to initiate state legislation designating the lake as a reservoir with certain unique provisions for its use.