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Analysis of Processes to Determine Site Suitability for a Marina at Bear Lake

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ANALYSIS OF PROCESSES TO DETERMINE SITE SUITABILITY
FOR A MARINA AT BEAR LAKE
UTAH/IDAHO

by

Charles J. Houghten

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of the requirements for the degree

of

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for a Marina at Bear Lake

Utah/Idaho

by

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The purpose of this thesis was to determine the criteria necessary for an analysis of site suitability for locating a marina at Bear Lake. Once criteria were defined and pertinent resource factors collected, a method to analyze the criteria was utilized to aid in the selection of the best site for locating this marina. Various methods to analyze site suitability were evaluated and the pros and cons of the chosen approach, a cluster analysis of existing resource transect data with hypothetical transect criteria, were discussed. Based on this study, no optimum sites were located at Bear Lake for a marina facility. However, it was concluded that transect number 3, near Garden City, is the most acceptable area for the development of a marina. It was also concluded that other areas of Bear Lake's shore zone are very sensitive and in order to protect the shore zone environment and water quality of Bear Lake, strict planning and development guidance needs to be generated and enforced for the Bear Lake shore zone.

(69 pages)

CHAPTER I

INTRODUCTION

Project Description

Problem Statement

Recreational use of Bear Lake Utah/Idaho has developed dramatically in the past two decades and this use is expected to expand as population growth occurs in the surrounding region, and as Bear Lake becomes an increasingly popular recreation area. Associated with the recreational growth is a boom in boating at Bear Lake and the need for docking and mooring facilities. To ensure their spaces, people have camped out up to a week in advance of the day that the Bear Lake State Park officials began issuing marina rental space ("Water Our Most Precious Resource", 1982). More marinas have been proposed to accommodate the demand to store boats, which currently exceeds the available docking facilities (Harrison, 1980; Morrow, 1982).

However, there is a great concern for the quality of Bear Lake's environment. Particular concern exists for water quality, and shore zone impacts related to new developments. The aesthetic and functional quality that a development has in relation to the natural and existing environments is also a concern at Bear Lake.

These environmental concerns extend to the placement and development of marinas. A marina may be considered as the single most potentially impacting shore zone development. Indeed, siting a marina for environmental and other considerations is a complex problem. Finding an ideal marina site that satisfies all conditions has been defined as a nearly impossible job (Beazley, 1969).

Planners, developers, and the public need to know what the most important criteria are in considering potential locations for marinas at Bear Lake. Since Bear Lake is an oligotrophic lake (low in nutrients) and has few naturally protected sites for a marina, the problem becomes more complex.

Current literature on the design and siting of a marina facility provides only general guidance in the development of site selection criteria. There appears to be no comprehensive guidelines for selecting marina site location criteria and the analysis of criteria for a lake such as Bear Lake.

Objectives

The primary objectives of this thesis are to develop site location criteria for a marina at Bear Lake and to analyze the processes available to determine site suitability for a Bear Lake marina. The site location criteria and a procedure to determine site suitability will then be used to select the best location for a marina at Bear Lake.

Methodology

This thesis describes the type of marina that would be suitable for Bear Lake. A compilation of characteristics that influence the location of a marina and factors that are impacted by the placement of a marina is presented and developed into site location criteria. Criteria are defined for optimum and minimum conditions.

Resource data that reflects site selection criteria are collected and summarized before being utilized in a suitability analysis.

Various processes for determining site suitability are discussed and a cluster analysis process is selected for use in analyzing Bear Lake shore zone data. Finally, a marina site is selected at Bear Lake using the collected resource information in the analysis for suitability based on the optimum locational criteria.

Study Area Description

Physical Setting

Bear Lake is located in Southeastern Idaho and Northeastern Utah, about 35 miles east of Logan, Utah. Bear Lake lies in the Bear Lake Valley, a depression within the Wasatch Mountain Range, at 5,924 feet msl. The Bear Lake Valley is embraced on all sides by mountains. The green, heavily forested mountains of the Bear River Range ring the lake and valley from the southwest to the northwest. The contrasting brown and gray sage covered, nearly vertical face of the Bear Lake Plateau lies to the east.

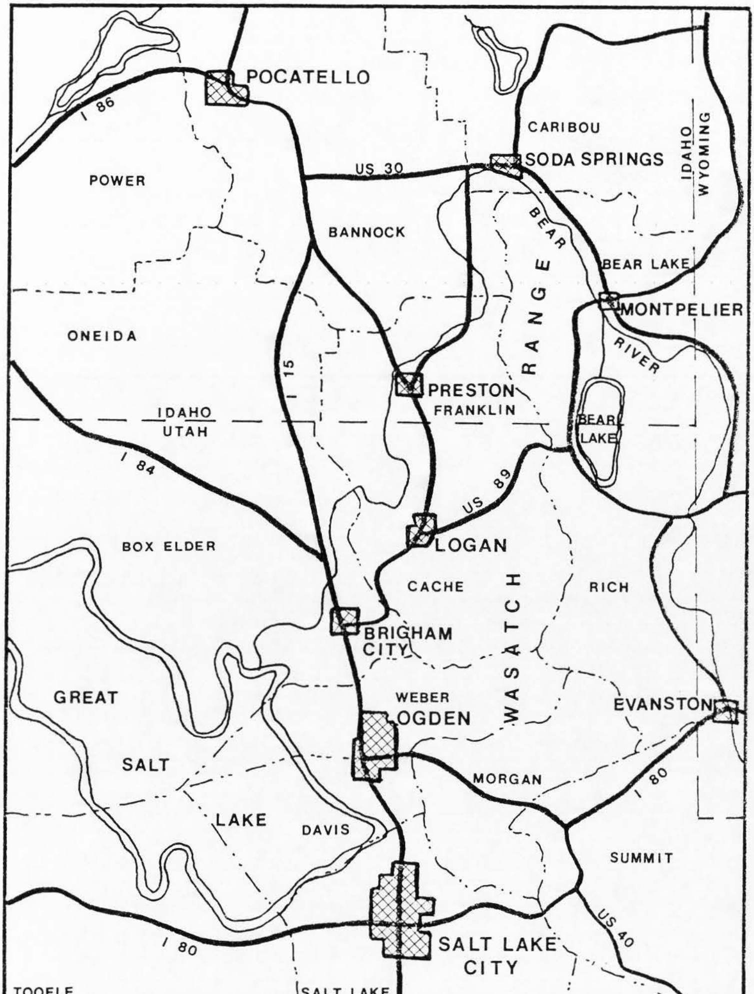
The lake is 19 miles long and contains approximately 67,000 surface acres (105 sq. mi.), about half (34,250 acres) in Rich County, Utah, and half (32,750 acres) in Bear Lake County, Idaho (USDA, 1976). At the state line, the lake is at its widest, at 7.6 miles. Bear Lake is considered to be oligotrophic, has a very regular shoreline with no natural bays or inlets, and is 208 feet deep at its deepest point.

Prior to 1911 Bear Lake had no direct connection with the Bear River drainage. During 1911 inlet and outlet canals were constructed at the north end of the lake to connect it with the Bear River. The lake's level is now artificially controlled by flowing Bear River water into the lake for storage, and releasing lake water later for power generation and irrigation. The fluctuation of lake levels is subject to regulations of the Bear River Compact of 1955 (Kaliser, 1972). The Bear River Drainage is the largest drainage in North America that does not flow to an ocean. The drainage begins in the Uinta Mountains of Utah, about 100 miles southeast of Bear Lake and flows through Wyoming, Idaho, and back to Utah prior to flowing into the Great Salt Lake, southwest of Bear Lake.

Historical Perspective

Once populated by many wildlife species, including bears, the Bear Lake Valley was the summer home to numerous Indian tribes and served as an intertribal rendezvous location as late as the 1870's (BLRC, 1979). The earliest non-Indian pioneers to visit the Bear Lake Valley were probably trappers from the Wilson-Price-Hunt expedition in 1811 (BLRC, 1979). Bear Lake was previously known as Little Lake (the Great Salt Lake then known as Big Lake), Miller Lake (after Joseph Miller, perhaps the first white man to explore the area), and Big Bear Lake (named by Donald McKenzie of the Columbia Fur Company in 1817 after the many black bears he encountered) (BLRC, 1979).

Permanent settlement of the Bear Lake Valley was initiated by Mormon pioneers in the 1860's and 1870's. Paris, Idaho, was the first settlement in the valley. Paris is now the Bear Lake County seat. The first settlements on the Utah side of the valley sprang up near the Round Valley and Laketown areas. Randolph, located above and south of the Bear Lake Valley, was settled in 1870 and is the Rich County seat.



BEAR LAKE

REGIONAL LOCATION

Agricultural development progressed in the Bear Lake Valley over the years, and has been the area's largest industry. The first resort at Bear Lake was built about 1920 at the Bear Lake Hot Springs. Bear Lake's recreational surge, however, didn't start until the 1950's, when people began to build summer cabins along the lake shore ("Bear Lake, About the Place and Its People", 1981).

Probably the most significant impact on recreational growth in the Bear Lake area has been in the private sector. In the early 1970's, recreational developers planned and built recreational condominiums, subdivisions, and RV parks. Many more developments are planned and indications are that the demand for more recreational facilities at Bear Lake will continue to grow (Utah, State of, 1980).

Current Conditions

The climate of the Bear Lake area has been described by early settlers as "nine months of winter, and three months of late fall" (BLRC, 1979, pg. 11). Winters can be extremely cold, with temperatures dropping below zero regularly. The lake freezes over on the average of four out of five years (Kaliser, 1972). As the lake thaws in the spring, chunks of ice often build up on the windward shore. The average wintertime low is 6°F. Summer weather is usually fair with high temperatures averaging about 84°F. Precipitation usually occurs during the winter months in the form of snow and the Bear Lake Valley averages 16 inches of precipitation annually (Jeppson, et al., 1968).

Growing seasons are very short due to the possibility of frost occurring in any month. However, a significant amount of agriculture occurs around Bear Lake and much of the surrounding lands are grazed by livestock. The shore zone of Bear Lake varies from scanty vegetation areas with rocks and cobble, to broad sandy beaches. The northwest portion of the lake shore consists of a shallow emergent marsh.

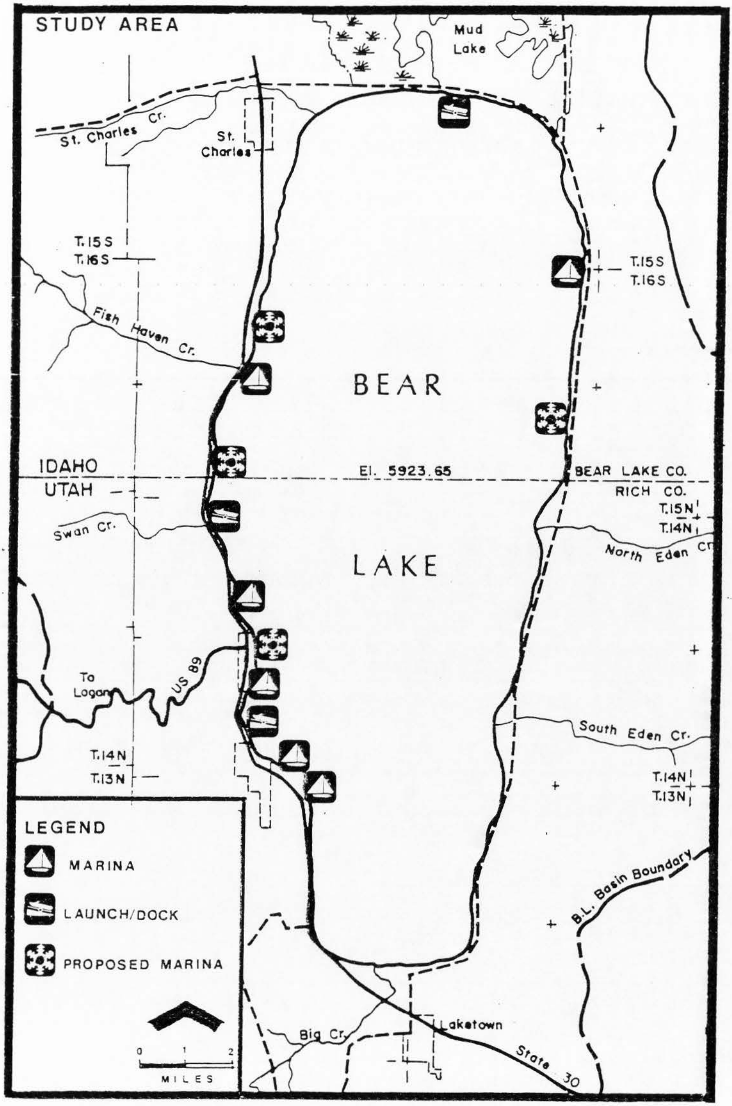
At the south end of the lake are Round Valley, Laketown, and the flat alluvial deposits of Big Creek. The east shore is still rather primitive with some developments scattered along the gravel road. The face of the Bear Lake Plateau rises quickly from the east shore, and provides little room for development. The west shore contains the main highway through the area and most of the developments. Garden City serves as the hub of activity along the west shore. Other communities include Fish Haven and St. Charles. The major recreational developments also occur along this route. Sweetwater, and Bear Lake West are the largest of these developments. Just beyond the north shore of Bear Lake is the Bear Lake National Wildlife Refuge which contains a diversity of marshes, grasslands, and open water areas.

Bear Lake and the surrounding Bear Lake Valley is still a relatively remote and rural area. The population for the surrounding area is approximately 10,000 (USDC, BOC, 1982a, 1982b). However, summertime populations on peak weekends can frequently bring over 30,000 people to the area (Utah, State of, 1980). Montpelier, Idaho, is the largest town in the Bear Lake Valley. Its 1980 population was 3,107 (USDC, BOC, 1982a).

Existing public recreation areas include the Bear Lake State Park and Marina (Utah), Rendezvous Beach State Park (Utah), North Beach State Park (Idaho), and scattered primitive camping and picnicking areas along the east shore. Recreational visitation at the lake's public parks has skyrocketed over the last decade. On Utah's public beaches, alone, use rose from an average of 70,000 visitors per year in 1970 to 150,000 in 1975 to over 200,000 in 1980 (Morrow, 1982).

Currently there are nine boat launching and docking facilities at Bear Lake. Six of these sites include marinas. These sites are shown in Figure 2 on the following page.

In summary, the current high demand for recreation at Bear Lake will continue to increase, as will the need for additional marinas. Due to the sensitive nature of Bear Lake's shore zone, it will be important to locate new shore zone facilities, such as marinas, in areas that will have the least impact on shore zone's resources.


STUDY AREA
Mud Lake
St. Charles Cr.
St. Charles
T.15S
T.16S
Fish Haven Cr.
BEAR
IDAHO
UTAH
El. 5923.65
BEAR LAKE CO.
RICH CO.
T.15N
T.14N
Swan Cr.
North Eden Cr.
LAKE
To Logan
US 89
South Eden Cr.
T.14N
T.13N
B.L. Basin Boundary
Big Cr.
Laketown
State 30
LEGEND
MARINA
LAUNCH/DOCK
PROPOSED MARINA
0
1
2
MILES

CHAPTER II

MARINAS

General Overview

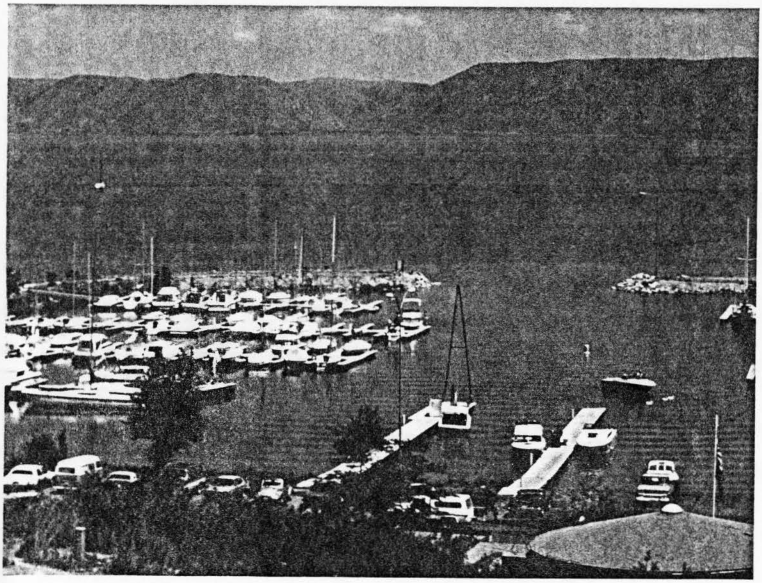
Several different sources generally provide different definitions of a marina. The National Association of Engine and Boat Manufacturers Incorporated of America first coined the word marina in 1928. They defined it as "a modern waterfront facility for recreational boats" (Adie, 1975, pg. 38). For the purposes of this thesis the following definition will be used: A recreational-craft harbor complex that includes all or some of the facilities utilized by the boating public. These facilities include launching, docking, mooring, fueling, and servicing components as well as vehicle parking, restrooms, and other personal services. The harbor complex is designed to protect the boats from waves and currents. (U.S. Army, 1974; BLRC, 1982).

Marinas vary in their design, structure, and function, and may be placed at the mouths of rivers or streams, within natural bays, in dredged lowland, or along the open shoreline and protected by breakwater-type structures (U.S. Army, 1974). Depending on the size and type of boats utilizing the marina, and other factors, design characteristics of the facility will vary. These characteristics include depth, size, shape, construction materials and methods, and the association with land-based facilities.

Bear Lake Marinas

Existing Types

All of the existing marinas at Bear Lake have similarities and most have their own uniqueness. All Bear Lake marinas have been constructed along the open shore and have been protected by the placement of fill material and rip rap that form breakwaters. All of the marinas have been developed almost solely for recreational use and function as launch points, docking and mooring sites. Most of the marinas have floating docks and platforms which are anchored to the lake bottom, shoreline, or breakwater, and fluctuate with lake levels.



Bear Lake Marina, Utah State Boat Park

Three marinas now provide refueling and servicing for motorboats at Bear Lake. The Bear Lake marinas now primarily handle sailboats which account for 85-90 percent of the boats on the lake. Sizes of sailboats on Bear Lake vary from 10' to over 30' (Morrow, 1982).

The marinas vary greatly in size. The Utah State Boat Park is the largest marina at 88,779 square feet and Azure Cove is one of the smallest at 10,991 sq. ft. (Lamarra, et al., 1982). The type of material used as rip-rap on the breakwaters varies from large rock, to a mixture of rock and indigenous sediment (Lamarra, et al., 1982). The design of marinas at Bear Lake have been defined as either being flow-through or containment. The flow-through design includes large 3' diameter pipes in the breakwaters to allow flushing of the marina. The containment marinas have no flow-through pipes. The Fish Haven Marina has a perennial stream flowing through it (Lamarra et al., 1982).

Recent Research

A recent study, "Physical, Chemical, and Biological Effects of Large Marinas on the Littoral Zone of Bear Lake" (Lamarra, et al., 1982), prepared for the Bear Lake Regional Commission, resulted in a number of significant findings, which include: 1) Due primarily to their poor design, the Bear Lake marinas constructed with pipes for a flow-through system did not function as such and are considered to be containment type marinas; 2) a significant difference in water quality was measured between marina breakwaters built of rock and marina breakwaters built of indigenous shore zone materials; 3) a containment marina design with a program to monitor water quality in marinas has been recommended for Bear Lake (Lamarra, et al., 1982).

Considerations for This Thesis

Function and Structure

The function of marinas to be considered in the further analysis of this study include the following:

1) To provide for boat launching and loading.
2) To provide for daily and seasonal docking.
3) To protect boats docked at the facility.
4) To provide parking, restrooms, and other facilities on adjacent upland.

The construction standards and structure of marinas to be considered in the further analysis of this study include the following:

1) The facility will be of a containment nature.
2) There will be no constraints on size or shape of the facility.
3) The facility will have minimal impact on water quality and other resources.
4) Material for breakwaters of the facility will be brought to the site and be made of large rocks previously found to be of suitable chemical composition so as to produce the least amount of contamination by foreign elements to water quality.

CHAPTER III

MARINA SITE LOCATION CRITERIA

The Need for Location Criteria

"Any design problem, from a region to a garden, must have criteria, or standards, on which judgments and actions may be based" (Toth, 1972, pg. 10). Not only is it important to establish criteria as a part of the process of determining the proper site for a facility such as a marina, it is also important to have a method for developing the criteria.

> The process of separating any whole into its parts in order to understand and define their nature, proportion, function and relationships is the art of analysis. In this process, the whole is separated into its parts in order to understand and define their essential quality, their comparative relations to each other with respect to size and quality, and their normal or characteristic action (Toth, 1972, pg. 10).

Prior to conducting an analysis into the site suitability for a marina at Bear Lake, an understanding of the function and structure of a marina is not only necessary, an understanding of the components or elements that make up a suitable site is also required.

When dealing with environmental planning, these components fall into two major categories: natural and cultural resources. These major categories are then broken down into sub-categories such as soils, vegetation, visual quality and accessibility. A further investigation into the functional, structural, and interactive roles that these sub-categories play in relation to the problem to be analyzed yields detailed elements which begin to help the researcher formulate specific criteria or standards (Toth, 1972).

In developing site location criteria for a Bear Lake marina the process involved in-depth research into marina requirements, and the relationship of environmental components to a marina facility. The goal of this research is to assure that the marina both satisfies the needs of man and the needs of the environment (USDI, FWS, 1974).

Factors and Standards for Consideration in Siting a Bear Lake Marina

Natural Resources

Hydrology

Wave and ice action. Wave and ice action can cause severe damage to docks, pilings, and other marina structures. It is desirable to select a site that will require the least amount of construction of protective structures to mitigate wave action. Sites that are the most susceptable to ice flows and the piling of ice by winds and waves should be avoided. Lake currents, prevailing winds, and locations of historical wave and ice damage are important factors to consider in marina site selection (Quinn, 1972; Neilson, 1982; "Packed Ice Takes a Toll Along the Shoreline," 1982). Sites that have a low potential for severe wave and ice action are considered optimum sites, areas that have moderate wave and ice action are considered minimum, and areas with high wave and ice activity are considered unacceptable.

Water quality. Since Bear Lake is unique to other lakes in the region in that it is oligotrophic, there is particular concern for the quality of Bear Lake's water. Recent research at Bear Lake's marinas indicates that the marinas contained higher levels of nutrients than the lake's littoral zone. Elevated levels of chlorophyll a, total phosphorus, total inorganic nitrogen, and less light transparency indicated the higher trophic states. The sources of nitrogen and phosphorus were believed to be primarily the result of sediment feedback and weathering of materials used as breakwaters. Phosphorus serves as a plant nutrient and can lead to accelerated eutrophication, algal blooms and other nuisance conditions. Nitrogen is toxic to fish in high concentrations and leads to eutrophication as well. Reduced light transparency, caused by suspended solids, or turbidity, may reduce plant and animal activity and may cause water bodies to have a brown, green, or muddy appearance. The increasing presence of chlorophyll a also indicates an increase in nutrients and primary biomass production (Lamarra, et al., 1982; Keyes, 1976; Cole, 1979).

Assuming that a containment marina will exhibit an increased trophic state, it is important to locate a Bear Lake marina on a site which does not already exhibit these characteristics. Regardless of whether a marina is contained or flushed, a significant factor in water quality will be the elimination of direct sources of pollution, such as surface runoff and flushing of a boat's sanitary facilities (U.S. Army, 1974).

Water depth. The standards for water depths at marinas range from four to twenty feet, with the six to ten foot range considered the best. However, on a lake such as Bear Lake, which may experience dramatic water level fluctuations from year to year, consideration must be given to the potential low water depths. Marinas should be located in deeper water to provide lower water temperature and minimize the need for dredging (Sargent, 1979; BLRC, 1982).

Soils

Silting and shoaling. Littoral drift often causes shoaling, or the development of a sand bar, at the entrances to harbors. Shoaling occurs most often in areas containing loosely compacted and fine soil types. Silting occurs when suspended material in the water settles out in quiet waters. Though designs of harbor facilities can decrease the occurance of these problems, areas containing silts should be avoided. Additionally, mouths of streams should also be avoided (U.S. Army, 1974; Chaney, 1939; ASPO, 1961).

Foundation conditions. The soil type in the shore zone, both in terrestrial and aquatic areas, is most desirable to be gravel for the supportive capacities. Bedrock, jagged shores and rocky areas should be avoided, as well as soil types that are primarily silts and clays (Sargent, 1979; ASPO, 1961). Not only are coarser materials found to be better suited for foundation conditions and resistance to wave and ice action, but the avoidance of fine soil types is necessary to reduce silting, shoaling, and turbidity problems.

Vegetation

The less vegetation biomass a site has the better suited it is for a marina. Rationale for this decision includes the fact that areas with more biomass will contain more nutrients, and the areas with more vegetation are considered to be greater in wetland wildlife value. Vegetation areas that support wildlife habitat are to be avoided.

Marsh areas, riparian zones, and wet meadows are the most significant habitats in shoreland areas (Clark, 1974).

Wildlife and Fisheries

Shore zone areas of high natural productivity or those locations which are considered essential or critical habitat for wildlife species are to be avoided (Clark, 1974). Important fish spawning areas are to be avoided at Bear Lake since they are designated by the Bear Lake Regional Commission as being highly sensitive sites (BLRC, 1979).

Geological Factors

Public facilities such as marinas should be set back from areas of active fault zones to avoid potential structural damage and hazards to the public (U.S. Army, 1974). It is desirable to locate facilities at least 2500' from active faults.

Topography

At least one-half of a site should be relatively flat. Variation in grade is acceptable. To aid in siting parking lots and to lessen the erosion potential, the lowest percent slope is considered to be the best site condition. Extremely steep areas may prove too costly to develop, and may cause an erosion problem (ASPO, 1961; Chaney, 1939).

Cultural Resources

Availability of Public Services

Marinas generally require access to potable water, utilities, and fire protection (ASPO, 1961). Vehicular access to the marina is also required. The closer a site is to existing roads and services, the better the site meets the needs of these requirements.

Visual Sensitivity

Proper design and landscaping can make a marina facility aesthetically appealing. However, extremely flat and open areas will be more sensitive and may impact the vicinity's visual qualities (USDI, BLM, 1980; U.S. Army, 1974).

Since much of the Bear Lake shoreline is very open and near public roads, visual sensitivity is high. Placement of a facility in these areas could be costly to mitigate for the visual intrusion and impact. It is most desirable to avoid areas of high scenic quality, and areas where a development would disrupt the existing visual absorptibility and landscape character.

The visual sensitivity of an area can also be determined by whether the site is located in the foreground, midground, or background as seen from a particular viewshed. Foreground is classified as highly sensitive, mid-ground as moderately sensitive, and background as low in visual sensitivity.

Space Standards

Though there are various standards available for determining particular size and dimension requirements for launching, docking, and parking, etc., most of these factors are not required for this study. Generally, a standard of two auto parking spaces per mooring space is accepted as a minimum. Depending on what other facilities may be at the marina, more or less upland acreage may be necessary. Areas that have a narrow shoreland strip between a shoreline road and the high water mark are not desirable. Generally, at Bear Lake, sites with the greatest distance between the road and high water mark will afford room for parking and facilities, room for expansion, and the ability to screen undesirable views or activities (Sargent, 1979). Optimum terrestrial land area can be defined as the greatest distance between the road and high water mark. At Bear Lake 1500' is defined as optimum and 450' as minimum.

Archeological and Historic Sites

Due to federal, state, and local regulations and policy, these areas should be avoided. Some sites may be given special treatment to enhance and protect their cultural value. Optimum site conditions will not have the occurence of these elements. Minimum conditions may allow the presence of one site.

Optimum and Minimum Criteria for Locating a Marina at Bear Lake

Based on the information outlined in the previous section and the actual resource data that was able to be collected, parameters for optimum and minimum conditions for locating a marina at Bear Lake may be developed. The resource data for Bear Lake is further defined in Chapter Four. Table 1 displays the fifteen resource factors and the optimum and minimum conditions for each category. Many of these defined conditions come from specific literature references, some come from data collected at Bear Lake and other factors are developed based on the judgment of this researcher.

TABLE 1

OPTIMUM AND MINIMUM CRITERIA FOR LOCATING A MARINA AT BEAR LAKE

	Resource Factor	Optimum	Minimum
1.	Terrestrial Slope (road to high water)	4%	12%
2.	Aquatic Slope (high water to low water)	15%	5%
3.	Water Depth (100' past low water)	15'	5'
4.	Milligrams of phosphorus/ gram of sediment	.033 milligrams	.200 milligrams
5.	Percent loss on ignition (organic sediment content)	0.42%	5.00%
6.	Vegetation Biomass (dry weight from meter square sample)	zero grams	60 grams
7.	Shore Zone Soil Type	gravel	sand
8.	Wave/Ice Action	low	moderate
9.	Terrestrial Land Area	1500' between road and high water	450' between road and high water
10.	Distance to Public Services	zero miles	six miles
11.	Visual Sensitivity	low	moderate
12.	Fishery	not in fish spawning area	not in fish spawning area
13.	Wildlife Habitat	not in critical wildlife habitat	not in more than one habitat type
14.	Distance from Fault Zones	greater than 1 mile	greater than 2500'
15.	Archeological or Historic Sites	none present	not more than one site present

CHAPTER IV

BEAR LAKE RESOURCE DATA

Summary

Resource information directly relating to the site location criteria for a Bear Lake marina was collected from a variety of sources. This chapter summarizes the key resource factors collected and further analyzed.

Resource Data Collection

Natural Resources

Hydrology

Wave and ice action. It is assumed that wave and ice action have enough similarities at Bear Lake to combine these two factors into one data category. However, more research in respect to this assumption is recommended. Information on wave and ice action was obtained primarily from Bryce Neilson, Utah Division of Wildlife Resources Biologist for Bear Lake, and this researcher's personal observation. Neilson states that there are three major current cells in Bear Lake which rotate clockwise. Aerial photography and other research bear out this fact. The most significant wave action occurs on the east shore from North Eden Beach to approximately a mile south of South Eden Beach. The location and direction of the lake's currents, the valley's prevailing northwesterly winds, and past observations of damaging waves were combined to classify areas of Bear Lake's shore zone as having low, medium, medium high, or high wave and ice action potential. Waves over six feet high are not uncommon during wind storms known locally as "Bear Lakers" (Neilson, 1982).

Water quality. To assure that a marina does not unduly accelerate the trophic state of the lake or the area it resides, water quality parameters were included in the resource analysis. A primary technique in determining lake trophic status is to calculate the phosphorus concentration in the lake. Additional measures of lake trophic status includes chlorophyll a concentrations, and light transparency (Secchi disc) (Dillon and Rigler, 1975).

During the summer of 1980, 47 transects (Figure 4) around the shore of Bear Lake were set up to coincide with each section line that intersects the shoreline (approximately every mile). The data, which was collected in conjunction with a water quality study of the Bear Lake marinas (Larmarra, et al., 1982), was used to analyze the benthic quality at each of these 47 transects. Four principal properties were collected and analyzed. These were:

1) The determination of milligrams of phosphorus per gram of sediment. Lake bottom sediment samples were taken at the shoreline, 60 meters (197') from shore and 120 meters (394') from shore. The results of each sample were recorded and then averaged for an average transect figure. The lowest sample was .033 mg and the highest sample had .327 mg.

2) The determination of the amount of organic material per sediment sample. Lake bottom sediment samples were taken at the shoreline, 60 meters (197') from shore and 120 meters (394') from shore. Once

dried, the sediments were weighed, ignited, and weighed again. The percent loss on ignition was recorded to represent the amount of organic material each sample contained. These results were recorded and then averaged for an average transect figure. The lowest sample was 0.42% and the highest sample was 30.26%.

3) Water samples were taken to determine the amount of chlorophyll a in the sample. However, this analysis failed in the laboratory for unknown reasons.

4) Secchi disc transparency was taken at each transect, but was determined to be an invalid sampling.

Since the light transparency sampling was invalid, the emphasis for determining potential sediment load and turbidity problems rests in analysis of the shore zone soil type and the percent of organics measured.

Water depth. By agreement under the Bear River Compact of 1955, the highest lake level at Bear Lake is to be 5923.65 meet msl. The agreement with Utah Power and Light sets a minimum controlled level of 5914.0 feet msl. The lowest recorded level of Bear Lake was on November 14, 1935, when the lake was at 5902.0 feet msl. The lake's level has only been recorded below 5914.0 feet msl three times since the enactment of the 1955 accord (5909.74' in 1961, 5913.41' in 1962, and 5912.91' in 1963) (Utah Power and Light, 1979; Hurt, 1982).

Water depths were measured along each of the 47 transects at 60 meters (197') and 120 meters (394') out from the shoreline. Also calculated was the water depth at 100 feet past the potential low water mark. The aquatic (littoral) slope was determined between this point and the high water mark under the assumption that the greater the slope, the better the aquatic conditions will be to avoid silting, shoaling and the need for dredging.

Soils

Shore zone soil types were recorded for the entire shore zone from the nearest road surrounding the lake to 120 meters (394') out into the lake. Generally, a soil classification could be registered for each of the 47 transects. The shore zone was classified as gravel, sand, rocks, jagged rock, silt, clay or a combination of these soil types. This data was collected primarily by field survey along the transects, with reference made to the USDA Soil Conservation Service, Rich County Soil Survey, Bear Lake Portion 1976, and the Idaho Water Resources Board, Special Soil Survey, Bear Lake County, 1968.

Vegetation

Measures of aquatic vegetation biomass were conducted along each of the 47 transects. Square meter sampling of the transect at the 60 meter (197') and 120 meter (394') points was undertaken with the sample being collected, dried and weighed. Most transects had no vegetation, the highest sample was 375 $g./m^2$.

Wildlife and Fisheries

Areas documented by the Bear Lake Regional Commission and this researcher as being important habitat for big game, game birds, raptors, waterfowl/waterbirds, and other mammals were recorded for the Bear Lake shore zone and adjacent upland. Areas known to be important to fish spawning were also documented from information provided by the Bear Lake Regional Commission (BLRC, 1979).

Geologic Factors

Fault zones in the Bear Lake Basin have been located by Robertson and Kaliser. The east shore fault is considered to be active and it is recommended that structures not be placed on or near this and other active faults. One of the largest recorded earthquakes in Utah was centered near the state line along the east shore fault on November 10, 1884 (Kaliser, 1972; Robertson, 1978; Arabasz, et al., 1979).

Topography

The percent slope from the road surrounding Bear Lake to the high water mark was calculated in accord with upland requirements.

Cultural Resources

Access to Public Services

In order to meet these requirements the linear road distance to the nearest town is calculated from a potential site. The town centers are Laketown, Garden City, Fish Haven, and St. Charles.

Visual Sensitivity

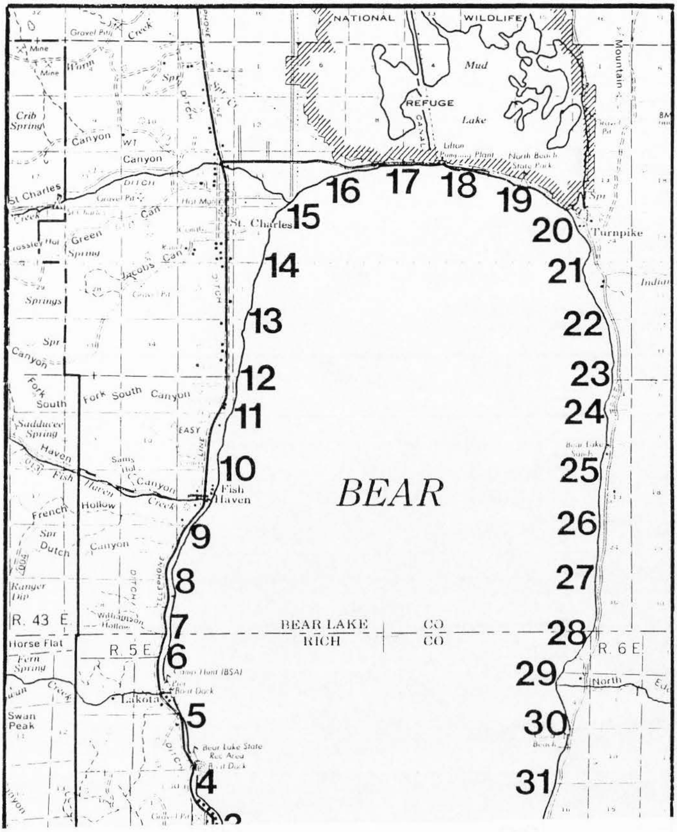
Visual sensitivity of potential sites was based on whether the shore zone was located in the foreground, midground, or background as seen from the surrounding roads and highways. Visual sensitivity included data collected by the Bear Lake Regional Commission (BLRC, 1979).

Space Standards

The distance from the nearest road to the high water line was measured to determine the available acreage for terrestrial development, and access.

Archeological and Historic Sites

Known sites were identified and cataloged by reviewing county master plans (BLRC, 1979).


NATIONAL
WILDLIFE
REFUGE
Mud
Lake
Mountain
BEAR
BEAR LAKE
RICH
CO
CO
R. 43 E.
R. 5 E.
R. 6 E.
St Charles
St. Charles
Fish Haven
Lakota
Turnpike
North Beach State Park
Bear Lake State Rec Area
Camp Hunt (BSA)
Crib Spring
Canyon
Green Spring
Jacobs Can
Springs
Fork South Canyon
Sadducee Spring
Haven
French
Hollow
Dutch
Ranger Dip
Horse Flat
Fern Spring
Swan Peak
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CHAPTER V

MARINA SITE SUITABILITY ANALYSIS

Analysis Processes

After the criteria has been developed and pertinent resource information collected the next step is the analysis of the data. This site suitability analysis may be accomplished by implementing various techniques, some of which are described below.

Hand-Drawn Map Overlays

The most common practice of site suitability analysis used by landscape architects and environmental planners incorporates the use of hand-drawn resource maps and the procedure of overlaying various maps to determine the relationship between different elements. Warren Manning, landscape architect, is credited as being the first to use data overlays as an analysis technique in his study of Billerica, Massachusetts in 1912 (Steinitz, et al., 1976).

In *Design with Nature*, Ian McHarg discussed an upgraded use of overlays in the analysis process. In an application of his method at Staten Island, McHarg describes the process of determining the areas on Staten Island which are most suitable for conservation.

> The salient factors selected for this search included: features of historic value; high-quality forests; high-quality marshes; bay beaches; streams; water-associated wildlife habitats; intertidal wildlife habitats, unique geological features; unique physiographic features, scenic land features; scenic water features; scarce ecological associations.

> Each of the constituent maps is an evaluation within the appropriate category, represented in five divisions, the lowest value shown as blank. All twelve maps were made into transparent negatives, which were superimposed and photographed. The resulting photograph represented the summation of all of the values employed and was therefore indicative of the areas most to least intrinsically suitable for conservation. This photograph was reconstituted into a single map, with the values for conservation indicated in five values. Thus the darker the tone, the greater the intrinsic suitability for conservation. (McHarg, 1969, pg. 110)

Another approach utilizing hand-drawn map overlays involves the use of resource maps as a data file system. In this process data variables are recorded once on transparent maps. These file maps are then reused for each suitability analysis conducted with the resultant composite being photographed or copied onto another transparency. The data variables for each overlay may be labeled by numeric values and/or colored with a range of different shades of one color (Steinitz, et al., 1976).

If the hand-drawn overlay mapping process had been used to determine suitability for a marina at Bear Lake, fifteen transparent resource maps would be prepared for the Bear Lake shore zone. The criteria defined as optimum under each resource condition for marinas would then be recorded onto a sixteenth transparent map. If the resource data files were designed to have darker shades represent the best conditions, then the resultant map would express the optimum sites as the darkest shade.

Computer Assisted Overlay Mapping

The development of geographic information systems (GIS) has given the resource planner a tool which expands on the basic hand-drawn overlay mapping process. GIS allows the user to permanently store resource data maps, rapidly make changes and assessments, as well as produce a visual display map.

Resource data is collected as it would be in the manual process and then is recorded (digitized) either in a grid cell or polygon format. Once all the resource data maps have been digitized and stored in the computer's memory, the user may select from various programs to overlay and analyze the resource data as desired.

If this system had been utilized to determine suitable sites for a marina at Bear Lake it would begin with a collection of shore zone resource information. Fifteen resource map files would be digitized into the computer. Once the shore zone data was stored, a program to call up all data defined as optimum location criteria for a Bear Lake marina would then be recorded by a predetermined symbol on a separate suitability map file. If the symbols used to locate suitable sites were representative of darker tones, a computer printout would then show the optimum sites as this dark tone.

Similarly, once the data was digitized, the user may apply different criteria or weigh the criteria differently to make different suitability analysis. One of the first systems developed for grid cell data analysis is the I.M.G.R.I.D. program (Information Manipulation System for Grid Cell Data Structures) (Sinton, 1976).

Other Analysis Methods

Other methods of analysis for site suitability include linear programming, development of simulation models, and the use of professional judgment. Linear programming is designed to allow the user to plug in variables into an equation with the goal of reaching the right combination of variables for optimization. Basically, this is a hit and miss operation working with a lot of unknowns. Simulation modeling is a program designed to use variables to imitate that which could happen with a given association of resource conditions. This process usually requires running a series of simulations and then analyzing them to see what happened and what's best. The use of professional judgment occurs in some degree in most all analysis' of this sort. However, to make a judgment for marina site suitability without the benefit of a detailed analysis of resource information would be highly suspect in this complex problem (Murray, et al., 1970).

Cluster Analysis

Since this researcher had worked with all of the previously mentioned approaches to suitability analysis, and because much of the data was already in the form of transects, a search for another method of analysis was initiated. It also was theorized that there may be a better way to analyze this unqiue ecological system, a shore zone, with both objective and subjective aquatic and terrestrial data.

During the spring of 1982 H. Charles Romesburg of the Department of Forestry and Outdoor Recreation at Utah State University was contacted to discuss the possible use of the cluster analysis computer program in which transect data could be analyzed on a hierarchical basis. After reviewing Romesburg's CLUSTAR and CLUSTID programs, this researcher approached him with a proposed process to analyze shore zone transects at Bear Lake for their suitability as marina sites.

The hierarchical cluster analysis program takes data in the form of a data matrix with objects and attributes. It calculates the resemblance or similarity of the coefficients and produces a tree (dendrogram or cluster gram) clustering the data for their similarity or dissimilarity. In other words, if all forty-seven transects (objects) at Bear Lake were run with their fifteen recorded resource values (attributes) through a cluster analysis, a tree showing which transects are most similar to each other would be produced on a computer printout. Transects most similar to each other will be closer together on the computer printed out tree (Romesburg and Marshall, n.d.).

The proposal for this phase of thesis research was to first run a cluster analysis for the 47 Bear Lake transects to see transect similarities. Then, to add in a hypothetical optimum transect as the 48th transect. If any of the actual transects clustered around this optimum transect, the theory would be that this transect would be the optimum site.

Transects

Prior to the summer of 1982 it was decided that the technique of cluster analysis utilizing the CLUSTAR program developed by Romesburg would be the principal method of analyzing site suitability for a Bear Lake marina. By this time 47 transects with fifteen resource data variables for both terrestrial and aquatic resource conditions were established and refined. These transects run from the perimeter road which encircles Bear Lake to 120 meters (394') into the lake. The transects are located on all of the section lines that intersect the Bear Lake shore. The location of the transects are shown in Figure 4.

Table 2 displays the Bear Lake shore zone transects and the data collected in relation to the fifteen resource factors developed to determine site suitability for a marina at Bear Lake. Definitions for each category are footnoted at the bottom of Table 2, page 36. Details on specific criteria and data appear in Chapters III and IV.

The Use of Cluster Analysis to Determine Site Suitability for a Bear Lake Marina

During the summer of 1982, transect data was keypunched onto computer cards according to the format required by the CLUSTAR program. The 47 transects became the objects and the 15 resource variables are referred to as attributes. The commands to run the cluster analysis were also punched up according to the CLUSTAR format and run through the VAX computer at Utah State University on July 12 and 13, 1982.

A brief summary of the process follows. All transect data has a numerical value. Resource data that was not already in numerical form was translated into numbers. There is no need to have pre-set numerical range. The program is designed to handle all numerical variations as it standardizes each set of values before the analysis. After the data is standardized by one of five methods (Average Euclidean Distance was used most often) a resemblance matrix is developed in metric by the computer program. The metric data is then clustered to produce a tree, or cluster gram, which shows degrees of similarity between the transects. Ten different cluster analyses were run for the Bear Lake transects. One run consisted of a similarity analysis of the 47 transects. The nine other cluster analyses used a different

TABLE 2

BEAR LAKE SHORE ZONE TRANSECT DATA

Transect No.	Terres-trial Slope	Aquatic Slope	Water Depth	Mg. Phosphorus /gram Sediment	Organic Content % Loss Ignition	Aquatic Veg. Biomass	Shore Zone Soil Type	Wave/Ice Action	Upland Area	Miles to Services	Visual Sensi-tivity	Fishery	Upland Wildlife Habitat	Fault Zone	Arch./Historic Sites
	%	%	ft.	mg.	%	g./m^2	5–1	6–0	ft.	mi.	5–1	2–0	6–0	5–0	1–0
1	5.6	4.2	5	.096	1.78	–	4	4	250	2	4	0	2	0	–
2	4.0	3.3	5	.101	5.41	–	3	4	225	1	3	0	2	0	
3	4.0	5.0	10	.042	1.72	.6	4	4	650	.5	2	0	2	0	
4	5.0	2.0	3	.058	2.09	–	4	6	225	1.5	5	0	1	0	
5	12.0	5.3	4	.061	3.31	105.	3	6	150	2.5	2	2	1	0	
6	14.6	2.0	3	.095	1.13	–	4	6	125	3.5	4	2	1	0	
7	22.0	5.0	5	.188	1.42	–	3	6	125	2.5	4	0	1	0	
8	18.0	1.6	2	.214	0.84	–	3	6	175	1.5	5	0	1	1	
9	6.0	1.1	2	.248	30.26	65.	1	6	125	.5	5	0	1	2	
10	3.2	0.6	1	.288	9.90	265.	1	6	1050	.5	3	0	2	5	
11	4.0	0.6	1	.130	1.82	375.	2	6	900	1.5	4	0	2	5	
12	2.7	0.5	2	.327	11.36	149.3	2	6	950	2	5	0	2	5	
13	2.0	0.3	2	.298	10.98	305.	2	6	1725	2	3	0	2	5	
14	0.9	0.2	2	.296	15.72	79.	2	6	3400	1	2	1	2	5	1
15	4.6	0.2	2	.249	15.26	–	2	6	150	1.5	2	2	1	1	
16	0.6	0.2	1	.163	4.04	–	2	6	950	2.5	4	1	1	0	
17	1.3	0.3	1	.182	1.88	–	3	6	400	3.5	5	0	1	0	

TABLE 2 (cont.)

Transect No.	Terres-trial Slope	Aquatic Slope	Water Depth	Mg. Phosphorus /gram Sediment	Organic Content % Loss Ignition	Aquatic Veg. Biomass	Shore Zone Soil Type	Wave/Ice Action	Upland Area	Miles to Services	Visual Sensi-tivity	Fishery	Upland Wildlife Habitat	Fault Zone	Arch./ Historic Sites
	%	%	ft.	mg.	%	$g./m^2$	5-1	6-0	ft.	mi.	5-1	2-0	6-0	5-0	1-0
18	2.5	0.4	1	.099	2.00	–	3	6	175	4.5	5	0	0	0	
19	5.0	.05	1	.281	2.85	–	3	6	100	5.5	5	0	0	0	
20	7.0	0.7	1	.208	3.64	–	3	6	75	6.5	5	0	1	1	
21	10.6	0.7	2	.078	5.95	–	3	6	400	7.5	4	0	2	5	
22	11.4	0.9	2	.067	3.90	–	4	6	500	8.5	2	0	1	5	
23	11.8	1.0	3	.105	2.18	–	4	6	300	9.5	3	0	2	5	
24	13.4	1.3	3	.114	2.65	–	3	6	450	10	5	0	2	5	
25	11.9	2.1	4	.117	15.65	.2	3	4	600	11	5	0	1	5	
26	6.8	1.7	10	.103	3.43	–	2	2	375	12	5	0	1	5	
27	10.7	18	5	.097	1.42	–	3	2	250	13	4	0	1	5	
28	6.7	1.5	4	.077	2.79	–	4	2	550	13	5	0	3	5	
29	2.9	4.7	8	.062	3.78	8.6	4	2	1950	12	4	1	2	5	1
30	8.4	4.7	8	.121	0.79	–	4	0	400	11	3	2	2	5	
31	18.5	17.5	15	.134	0.74	–	3	0	175	10	4	2	0	0	–
32	28.0	30.0	25	.120	1.07	–	4	0	125	9	4	2	0	0	
33	14.8	10.0	15	.076	0.54	–	4	0	225	8	4	2	1	1	
34	2.1	14.0	15	.077	1.36	–	4	0	1600	7	3	0	0	2	1
35	10.7	5.0	10	.101	0.88	–	4	0	400	6	4	0	1	0	
36	17.0	14.0	15	.081	1.08	–	2	2	100	5	5	0	0	0	

TABLE 2 (cont.)

Transect No.	Terres-trial Slope[1]	Aquatic Slope[2]	Water Depth[3]	Mg. Phosphorus /gram Sediment[4]	Organic Content % Loss Ignition[5]	Aquatic Veg. Biomass[6]	Shore Zone Soil Type[7]	Wave/Ice Action[8]	Upland Area[9]	Miles to Services[10]	Visual Sensi-tivity[11]	Fishery[12]	Upland Wildlife Habitat[13]	Fault Zone[14]	Arch./ Historic Sites[15]
	%	%	ft.	mg.	%	$g./m^2$	5–1	6–0	ft.	mi.	5–1	2–0	6–0	5–0	1–0
37	11.3	14.0	15	.071	0.62	–	3	2	150	4	3	0	0	0	
38	7.0	2.3	15	.076	1.52	–	3	2	150	3	5	0	1	0	
39	2.3	1.0	5	.073	1.17	–	4	4	275	2	5	0	1	0	
40	2.5	0.7	3	.057	4.71	–	4	4	300	1	4	0	1	0	
41	0.7	1.1	4	.095	1.24	–	3	4	2300	1.5	3	0	2	0	
42	7.0	1.4	3	.092	0.43	–	3	4	100	2	5	0	2	0	
43	12.0	2.0	4	.083	0.51	8.	4	2	150	3	5	0	3	0	
44	22.0	3.6	5	.033	0.81	–	4	2	75	4	5	0	2	0	
45	12.0	3.6	5	.048	1.08	–	4	2	100	4	5	0	2	0	
46	0.9	4.2	5	.096	0.42	–	4	2	1550	3.5	1	2	1	0	
47	2.2	2.6	3	.068	1.20	–	4	4	900	3	3	2	3	0	

1 Road to high water
2 High water to low water
3 100' past low water
4 Average from aquatic sediment samples
5 Average from aquatic sediment samples
6 Dry weight from meter square sample
7 Gravel = 5; rock and/or sand = 3; clay, silt, jagged rock = 1
8 Low = 6; medium = 4; medium high = 2; high = 1
9 Road to high water
10 Miles to nearest existing town center
11 High = 5; moderate = 3; low = 1
12 Presence of spawning area = 2
13 Presence of any = 1; critical area x 2
14 Fault w/in transect = 5; 1/8 mi away = 4; 1/4 mi away = 3; 1/2 mi away = 2; 1 mi away = 1
15 Presence = 1

hypothetical 48th transect each time. These hypothetical transects are defined as the following:

48-1 The optimum marina locational criteria

48-2 The optimum Bear Lake marina locational criteria

48-3 The worst site conditions for a Bear Lake marina

48-4 Strongest restrictions on terrestrial slope, aquatic slope, water depth, and upland area

48-5 Reduced restrictions on terrestrial slope, aquatic slope, water depth, miles to services, and visual sensitivity

48-6 Reduces restrictions as in 48-5, but completely reduces restrictions on miles to services, visual sensitivity, and archeological/historical sites

48-7 A compromise between optimum conditions and minimum conditions for all resource factors

48-8 A compromise between optimum conditions and minimum conditions for all resource factors as in 48-7, with more restrictions on terrestrial slope, water depth, vegetation biomass, wave/ice action, upland area, miles to services, wildlife, and fault zone proximity.

48-9 The minimum site conditions acceptable for a Bear Lake marina

The values for each of these hypothetical data transects are shown in Table 3.

The first run on the computer was of the 47 transects to determine their similarities. Cluster Gram A, Figure 5, displays the similarities between transects at Bear Lake. Transects 4 and 39 are shown to be most alike. Each branch of the tree, from top to bottom, shows groups

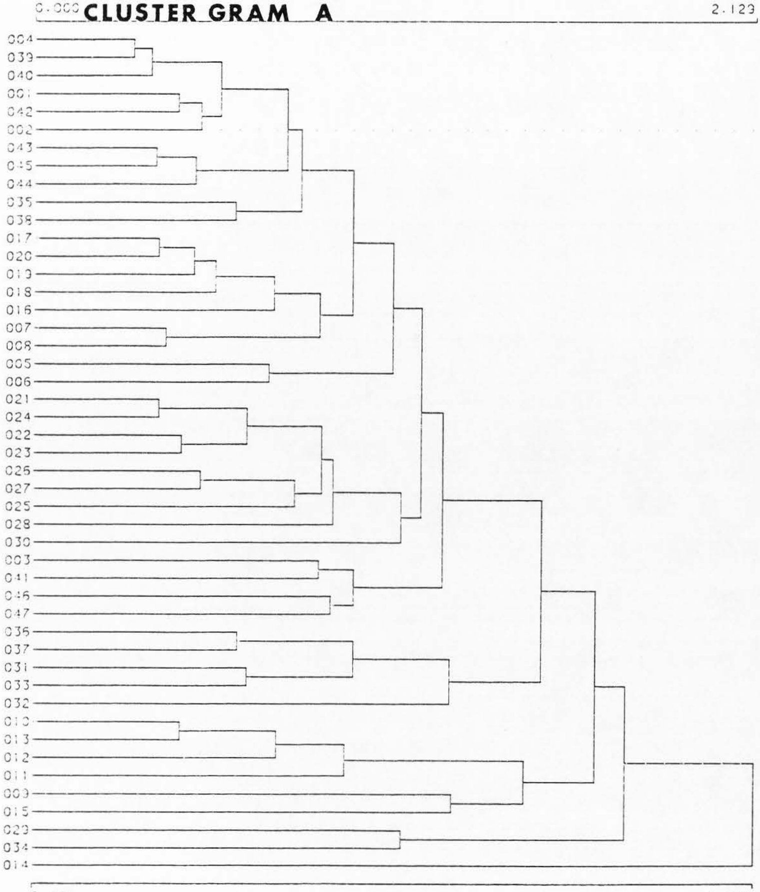
TABLE 3

VALUES FOR THE NINE HYPOTHETICAL 48TH TRANSECTS

Transect No.	Attributes														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
48-1	4	15	20	0	0	0	5	6	1500	0	1	0	0	0	0
48-2	4	15	15	.033	0.42	0	4	6	1000	.5	1	0	0	0	0
48-3	28	0.2	1	.327	30.26	375	1	0	75	13	5	2	3	5	1
48-4	1	30	25	.033	0.42	0	4	6	3400	.5	1	0	0	0	0
48-5	.5	10	10	.033	0.42	0	4	12	900	2.5	2	-2	0	0	0
48-6	.5	10	10	.033	0.42	0	4	12	900	9990	9990	0	0	0	9990
48-7	8	10	7.5	.125	3.95	28.3	3.19	5	600	4	2	0	1	1	0
48-8	5	10	10	.125	3.95	0	4	6	750	3	2	0	0	0	0
48-9	12	5	5	.200	5.00	60	3	4	450	6	4	1	1	2	1

Note: See Table 2 for attribute (resource) definitions.

CLUSTER GRAM A



of similar transects. Transect 14, at the bottom of the tree, is the least similar to all other transects. The range of dissimilarity is shown on the horizontal axis at the bottom of the figure.

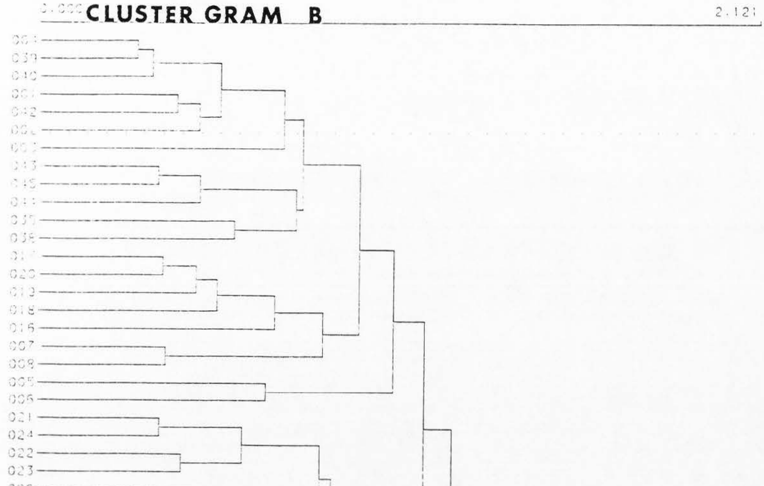
The next run (48-1) added a hypothetical 48th transect. The attributes of this transect were established to represent the optimum locational criteria for a marina. Cluster Gram B, Figure 6, displays no transects clearly clustered with this 48th transect. The conclusion then was that there are no optimum sites for a marina at Bear Lake, based on this locational criteria.

The next run (48-2) slightly reduced the constraints on the optimum conditions. The resource factors for optimum matched the best existing values for each resource at Bear Lake. In other words, if transect 44 had the lowest mg. of phosphorous per gram of sediment at .033 mg., then .033 was listed as optimum for transect 48-2. As shown in Cluster Gram C, Figure 7, again, no Bear Lake transects clearly clustered with this 48th transect. However, transects 31, 32, 33, 36. and 37, clustered the closest to this hypothetical optimum transect.

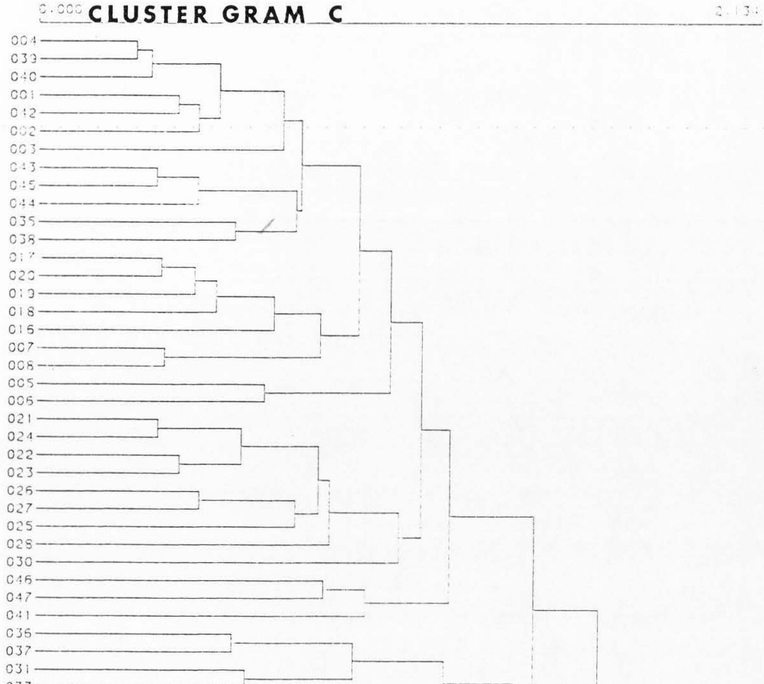
Run 48-3 was designed to analyze the worst possible transect for a marina. Transect 48-3 was coded to record all of the worst existing resource conditions for each attribute. Cluster Gram D, Figure 7, shows that transect 14 is the worst location for a Bear Lake marina based on this analysis.

Runs 48-4, 48-5, and 48-6 were all runs that made various changes in the restrictions of the optimum criteria, but in the judgment of this researcher, if any Bear Lake transects clearly clustered around any of these three 48th transects they could be considered the best sites. Still, no transects clearly clustered with these criteria.

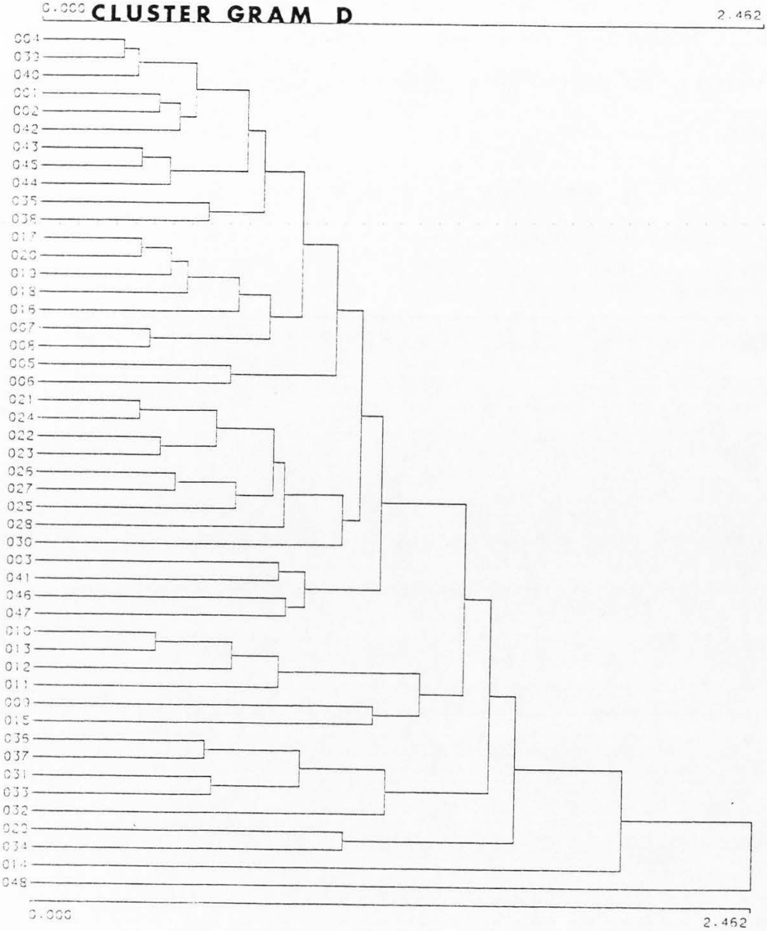
CLUSTER GRAM B



CLUSTER GRAM C



CLUSTER GRAM D



The next two runs were developed as a compromise between the optimum and minimum criteria. These runs, 48-7 and 48-8, consist of resource conditions that fall between that defined as optimum at Bear Lake (transect 48-2), and minimum, which was run as 48-9. In both runs 48-7 and 48-8, Bear Lake transect 3 clearly clustered with these moderate conditions. Figure 9, Cluster Gram E, displays the results of run 48-7. This cluster gram shows that Bear Lake transect 3 clearly clusters with the conditions defined in the hypothetical transect 48-7. It can also be interpreted from this figure that the eleven transects above transect 3 are the next closest in similarity, and therefore quality, to transects 3 and 48. Transect 14 is shown to be the least similar, as well as the least acceptable site for a marina, as are the bottom nine transects on the figure.

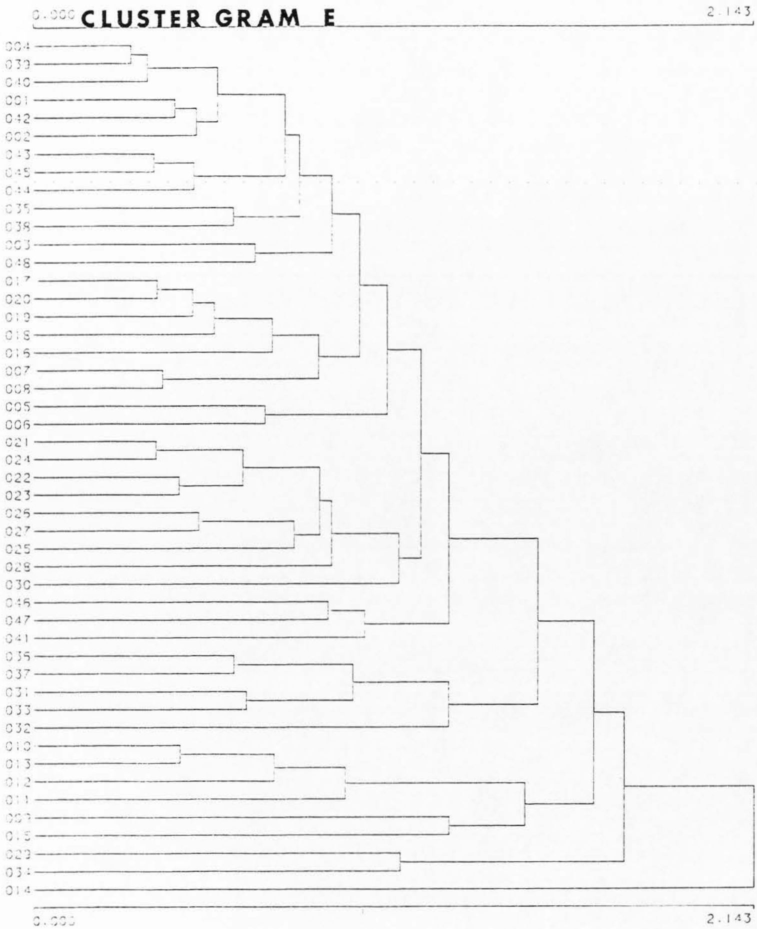
In run 48-9, Bear Lake transects 29 and 34 were found to be most similar to the resource conditions defined as minimum.

When transect 3 turned up as the moderately acceptable site, a closer look at the site conditions was undertaken. Additionally, other methods of analysis of the transects by not standardizing the data, and using other correlations were run for transects 48-1 and 48-7. The results were basically the same. Bear Lake transect 3, although not optimum, was clearly the best site for a marina at Bear Lake based on this analysis.

Discussion of the Analysis Process

The analysis conducted in this thesis is a complex one. Few studies discuss the important and complex interaction of resources within a shore zone, and few have involved a detailed analysis of both

CLUSTER GRAM E



terrestrial and aquatic resources. The problem becomes even more complex when the requirements and impacts of a shore zone marina are added to the analysis.

There certainly are pros and cons to various analysis processes and this case is no exception. The use of the cluster analysis program proved to be very satisfactory. Its major benefit in this analysis was the speed at which one could quickly record resource variables and analyze them, make changes and analyze again. The major drawback is that one cannot quickly "see" where resource data is in relation to the ground as one can in mapping.

Of all the principal site selection processes discussed in this thesis, all would be basically similar in the initial steps. Location criteria would be developed and is the same information utilized in any process, assuming it can be mapped, recorded, etc. as collected. However, it is often difficult to map some resource variables. For instance, some of the aquatic data collected measured in milligrams or grams, were already averaged for the transects. This data would likely be further generalized to be shown on a map overlay. Milligrams of phosphorus probably would have been reduced to ranges of numbers or high, medium, and low. Can an important resource factor such as this be rationally generalized? The preparation of suitability maps for manually and/or digitized input into the computer is a labor intense process, and one knows that the process of overlaying 15 resource maps manually on a light table can become a complicated act. In discussing the hand-drawn map overlay process, Steinitz, et al., (1976, pg. 449) stated "Finally, on the light table, we pray that we can make sense of it in combination with a limited number of other data maps."

The process used in this research of clustering transect resource data around hypothetical data transects has similarities to simulation modeling and linear programing. This process worked very well, and one would expect that analysis of similar relationships such as stream corridors, highway and power line networks could also make use of this method. Though this analysis process could be used in various types of research, it is highly probable that when researching an entire county or region, a computer program which analyzes cellular or polygon data may be more suitable. However, this is an area where further research may prove otherwise. And one would like to see further research on the use of the cluster analysis and its compatability with other areas of the landscape architecture and environmental planning discipline.

CHAPTER VI

CONCLUSIONS

Within the scope of this thesis specific site location criteria were developed for a Bear Lake marina, a unique site suitability analysis process was developed and found useful, and a specific site selected for a Bear Lake marina.

Site Suitability

Though it does not meet the ideal, transect number 3 appears to lend itself well to a marina facility. A look at the specific resource information for this site supports this conclusion.

Resource Factors of Transect #3

1) The terrestrial slope of this site is 4%, a very reasonable figure, and considered in the optimum range.
2) The aquatic slope of transect 3 is 5%, though defined as the minimum condition, it is well above the norm for the relatively flat Bear Lake littoral zone.
3) The water depth measured from the low water point is 10 feet, which is very adequate.
4) The milligrams of phosphorus per gram of sediment is .042 mg. and one of the lowest and best samples.
5) The organic content of sediment measured by percent loss on ignition is 1.72%, and again is one of the best samples at Bear Lake.

6) Aquatic vegetation biomass is above the norm for the lake since there is aquatic vegetation in the area, but it is not extensive. Dry weight was at .6 gram/m^2.

7) Shore zone soil type for site 3 is sand and gravel, a very satisfactory condition.

8) Wave/ice action is defined as medium.

9) Linear distance for upland use measures 650' from the road to the high water line, and is about average.

10) It is only .5 miles to services as this site is located in Garden City.

11) Visual sensitivity is defined as moderately low.

12) There is no known fishery spawning in the area.

13) The area is considered as wildlife habitat for some species, but meets the minimum criteria.

14) The transect does not intersect a known active fault.

15) There are no known archeological/historic sites existing at the site.

These conditions indicate a satisfactory and acceptable site. The biggest drawbacks relate to aquatic slope, which means some dredging may be required, and some displacement of wildlife may occur. The displacement of wildlife in this area can be expected from any further development of this site. If other more extensive upland and wetland habitat is preserved for wildlife, then the displacement becomes negligible.

Though it is the opinion of this researcher that transect 3 is suitable for a marina, one should not assume that this document justifies actual construction. Further research may well be in order.

Overall Suitability of Bear Lake

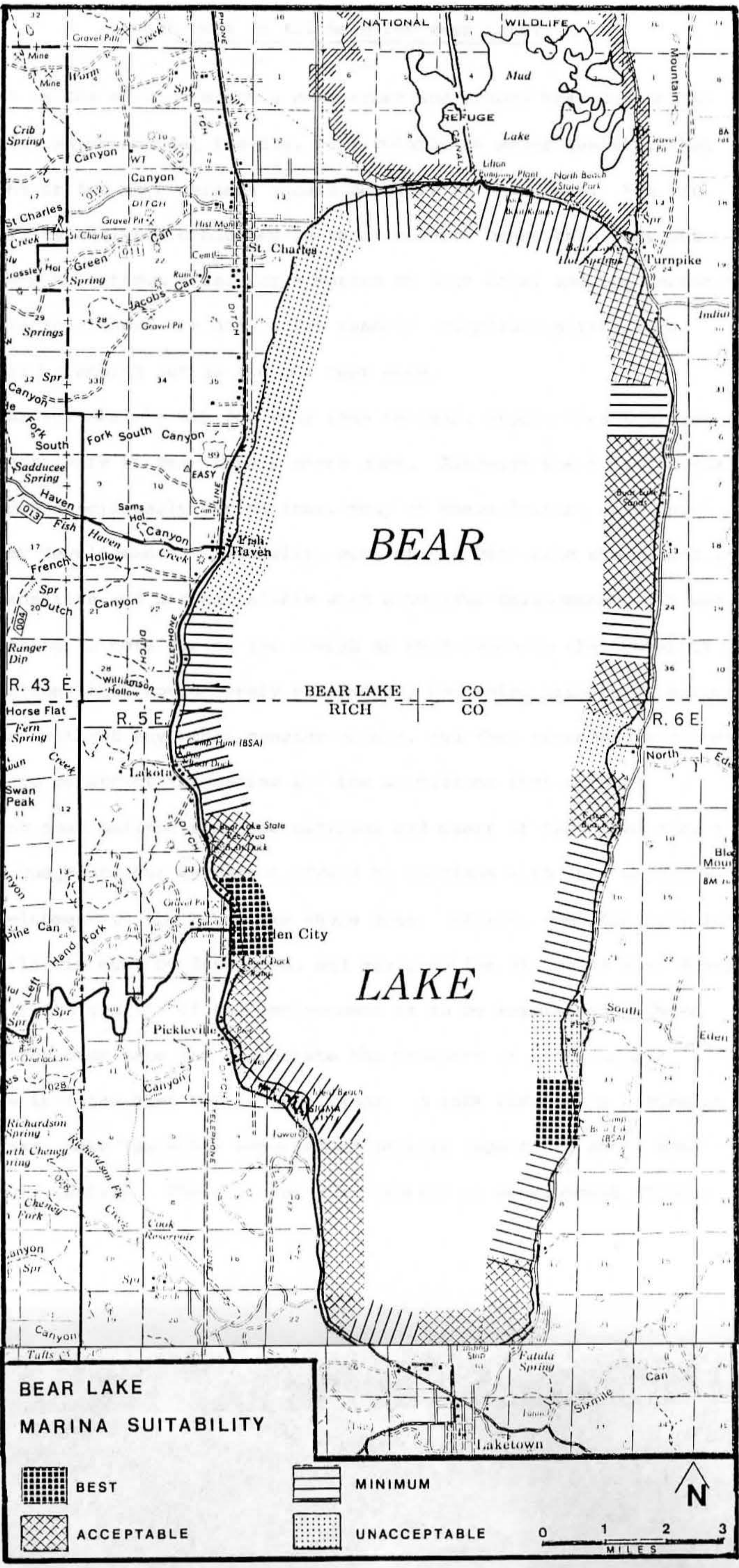
Figure 10 generalizes the data collected and analyzed during the research of this project and displays the best sites, acceptable sites, sites with minimum conditions and unacceptable areas for locating a marina at Bear Lake. This map is a composite of the various cluster grams. Each of the four groups represents the general clustering of the 47 transects.

The sites designated as having the best site suitability for a Bear Lake marina include transect 3 and transect 35. Although transect 3 is considered the best site at Bear Lake, transect 35 was the only other transect to be clearly better than average.

The sites designated as having acceptable marina site suitability are varied in their nature. Most have narrow upland areas, with high visual sensitivity, but with relatively good aquatic conditions. Although the sites clustered together as the next best sites to the various hypothetical transects, many of these sites are probably closer to containing minimum site conditions.

Many of the transects lumped into the minimum category of site suitability are more likely to be labeled as marginal sites. All of these transects have at least one major drawback and many of these sites have site conditions that do not meet minimum criteria for one or more of the resources.

The unacceptable sites are clearly unsatisfactory in terms of criteria established in this thesis. Many of these sites are in the emergent marsh area and most sites have water quality values beyond minimum standards.


BEAR LAKE
MARINA SUITABILITY
BEST
ACCEPTABLE
MINIMUM
UNACCEPTABLE
0 1 2 3
MILES
N
BEAR
LAKE
BEAR LAKE CO
RICH CO
NATIONAL WILDLIFE REFUGE
Mud Lake
St. Charles
Fish Haven
Garden City
Pickleville
Laketown
Turnpike
North Beach State Park
Camp Hunt (BSA)
Lakota
Bear Lake State Rec. Area
R. 43 E.
R. 5 E.
R. 6 E.

What Does It All Mean for Bear Lake?

It is the opinion of this researcher and others that due to the potential environmental impacts, particularly on water quality, that only one or two more marinas should be built at Bear Lake. The site suitability analysis conducted in this research bears this fact out. There are no optimum sites for a marina at Bear Lake, and the research suggests that there are only a few readily acceptable sites, with transect 3 standing out as the one best site.

The suitability map for Bear Lake marinas, Figure 10, summarizes the sensitivity of Bear Lake's shore zone. Although the criteria was developed specifically for marinas, many of these factors also apply to other developments. Generally, much of the Bear Lake shore zone is very sensitive and not compatible with extensive development. It was interesting to note during the course of this research the number of publications that would merely recommend a protected site for a marina's location without any other considerations, and then recommend actions on how to construct the marina for the conditions that existed.

One must believe that the citizens and users of Bear Lake concur in the judgment that we cannot afford to continue with this approach to development in the Bear Lake shore zone. Strict, specific site location criteria must be developed, and analyzed for all shore zone developments if the quality of the environment is to be maintained. Those that enjoy Bear Lake can appreciate the prospect of avoiding the example that has been set at Lake Tahoe. A lake similar in nature to Bear Lake, Lake Tahoe has experienced serious impacts to shore zone and water quality. There is now a moritorium on development at Lake

Tahoe and a master plan pending to assure that the quality of this area does not degrade any further.

In conclusion, development will continue to occur at Bear Lake; but, hopefully, only when the nature of the impacts that a development may cause are clearly understood. In support of environmental quality for all, a strict master plan to guide development, research, preservation and monitoring of the Bear Lake environment should be developed and enforced.

REFERENCES

Adie, Donald W. Marinas, A Working Guide to Their Development and Design. Boston: Cahners Publishing Co., Inc., 1975.

American Society of Planning Officials. Recreational Boating Facilities. ASPO Planning Advisory Service. Report No. 147. Chicago: ASPO, 1961.

Arabasz, Walter J.; Smith, Robert B.; and Richins, William D. Earthquake Studies in Utah, 1850 to 1978. University of Utah, 1979.

"Bear Lake, About the Place and its People." Herald Journal. Logan, Utah, May 31, 1981, p. 7.

Bear Lake Regional Commission. Land Use Guides for Rich County, Utah and Bear Lake County, Idaho. Fish Haven, Idaho, 1979. (typewritten)

Bear Lake Regional Commission. Water Quality Management Plan, Bear Lake Marinas. 1982. (unpublished)

Beazley, Elisabeth. Designed for Recreation. London: Faber and Faber, 1969.

Chaney, Charles A. Marinas, Recommendations for Design, Construction and Maintenance. New York: National Association of Engine and Boat Manufacturers, Inc., 1939.

Clark, John. Coastal Ecosystems, Ecological Considerations for Management of the Coastal Zone. Washington D.C.: The Conservation Foundation, 1974.

Cole, Gerald A. Textbook of Limnology. St. Louis: The C.V. Mosby Co., 1979.

Dillon, P.J. and Rigler, F.H. "A Simple Method for Predicting the Capacity of a Lake for Development Based on Lake Trophic Status." Journal of the Fisheries Research Board of Canada. Vol. 32, No. 9, 1975, pp. 1519-1531.

Harrison, Al. Bear Lake Regional Commission, Fish Haven, Idaho. Interview, June 1980.

Hurt Jack. Utah Power and Light. Lifton, Idaho. Interview, May, 1982.

Idaho Water Resources Board. Special Soil Survey, Bear Lake County. 1968.

Jeppson, R.W.; Ashcroft, G.L.; Huber, A.L.; Skogerboe, G.V.; and Bagley, J.M. Hydrologic Atlas of Utah. Logan, Utah: Utah Water Research Laboratory, 1968.

Kaliser, Bruce N. Environmental Geology of Bear Lake Area, Rich County, Utah. Salt Lake City: Utah Geological and Mineralogical Survey, 1972.

Keyes, Dale L. Land Development and the Natural Environment: Estimating Impacts. Washington D.C.: The Urban Institute, 1976.

Lamarra, Vincent; Lentz, David; and Thomas, Craig. The Physical, Chemical, and Biological Effects of Large Marinas on the Littoral Zone of Bear Lake. 1982. (unpublished)

McHarg, Ian L. Design with Nature. Garden City, N.Y.: Doubleday & Co., Inc., 1969.

Morrow, David. Bear Lake State Park Superintendent, Garden City, Utah. Interview, June, 1982.

Murray, Timothy; Rogers, P.; Sinton, D.; Steinitz, C.; Toth, R.; and Way, D. Honey Hill: A Systems Analysis for Planning the Multiple Use of Controlled Water Areas. Harvard University: Dept. of Landscape Architecture, 1970.

Neilson, Bryce. Utah Division of Wildlife Resources, Biologist. Garden City, Utah. Interview. June, 1982.

"Packed Ice Takes a Toll Along the Shoreline". The New York Times. Feb. 14, 1982, pg. 2.

Quinn, Alonzo. Design and Construction of Ports and Marine Structures. New York: McGraw-Hill Book Co., 1972.

Robertson, George C. III. "Surficial Deposits and Geologic History, Northern Bear Lake Valley, Idaho." Masters Thesis, Utah State University, Logan, Utah, 1978.

Romesburg, H. Charles, and Marshall, Kim. CLUSTAR and CLUSTID, Programs for Hierarchical Cluster Analysis. Utah State University. No date.

Sargent, Frederic O. Rural Water Planning. South Burlington Vermont: Author. 1979.

Sinton, David F. The User's Guide to I.M.G.R.I.D. Harvard University: Dept. of Landscape Architecutre. 1976.

Steinitz, Carl; Parker, Paul; and Jordan, Lawrie. "Hand-Drawn Overlays: Their History and Prospective Uses." Landscape Architecture. Sept. 1976, pp. 444-455.

Toth, Richard. "Criteria in Land Planning and Design". Impact of Water Resources Development. Vol. 1, No. 2, 1972, pp. 10-13.

United States Army, Corps of Engineers. Small Craft Harbors: Design, Construction, and Operation. Fort Belvoir, VA: U.S. Army Coastal Engineering Research Center, 1974.

United States Department of Agriculture. Land Resource Data Working Paper for Bear River Basin Cooperative Study. 1976.

United States Department of Agriculture, Soil Conservation Service. Rich County Soil Survey, Bear Lake Basin Portion, Rich County, Utah. 1976.

United States Department of Commerce, Bureau of the Census. 1980 Census of Population, Idaho. Washington D.C.: U.S. Printing Office, 1982a.

United States Department of Commerce, Bureau of the Census. 1980 Census of Population, Utah. Washington D.C.: U.S. Printing Office, 1982b.

United States Department of the Interior, Bureau of Land Management. Visual Resource Management Program. Washington D.C.: U.S. Printing Office, 1980.

United States Department of the Interior, Fish and Wildlife Service. Planning for Wildlife and Man. Washington D.C.: U.S. Printing Office, 1974.

Utah Power and Light. Water Surface Elevation, Bear Lake at Lifton. 1979. (typewritten)

Utah, State of. Bear Lake Impact Study. Salt Lake City: Architects/ Planners Alliance, 1980.

"Water Our Most Precious Resource." Herald Journal. Logan, Utah, May 30, 1982, p. 27.

APPENDICES

Appendix A

Bibliography

Nixon, Scott W.; Oviatt, Candace A.; and Northby, Sharon L. Ecology of Small Boat Marinas. Kingston RI: University of Rhode Island, School of Oceanography, 1973.

Romesburg, H. Charles, and Marshall, Kim. CLUSTAR and CLUSTID, Computer Programs for Hierarchical Cluster Analysis. Belmont, CA: Lifetime Learning Publications, 1984.

Romesburg, H. Charles. Cluster Analysis for Researchers. Belmont, CA: Lifetime Learning Publications, 1984.

United States Army Corps of Engineers. Guidelines for the Environmental Impact Assessment of Small Structures and Related Activities in Coastal Bodies of Water. McLean, Virginia: The Mitre Corp., 1975.

Appendix B

Scientific Methodology Used in Determining Bear Lake Benthic Quality

In cooperation with a Bear Lake Regional Commission water quality study of Bear Lake marinas, three properties of Bear Lake's littoral zone were collected during the research of this thesis. The methods used in this portion of the data collection phase are referenced as follows:

American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 15th Edition. Washington D.C.: American Public Health Association, 1980.

1) Determination of Phosphorus in Transect Sediment Samples, p. 409 (Phosphorus).

2) Determination of Aquatic Vegetation Biomass, p. 985 (Vegetation Mapping Methods).

3) Determination of Percent of Organic Material in Sediment, p. 95 (Total Volative and Fixed Residue at 550C)

Appendix C

Glossary

Benthic: Bottom region of a lake.

Breakwater: An artificial barrier used to diminish the force of waves and currents.

Cluster Analysis: A method of determining the similarity or dissimilarity between pairs of objects. The objects are made of attribute data, and are presented in the form of a tree (dendrogram or cluster gram) which summarizes the relationships between the objects. In this thesis the objects are transects which consist of resource data variables (attributes).

Eutrophic: High in nutrients.

Hypothetical Transect: A transect used in the analysis of other transects. This transect consists of resource data variables which represent particular qualities, such as optimum resource conditions.

Littoral Zone: The aquatic zone which extends from the lake shore to a lakeward depth were light transparency and rooted aquatic plants become scarce.

Location Criteria: Information which describes the resource conditions which are necessary to support a particular activity or function.

Minimum: In reference to minimum resource conditions in location criteria, it is the set of data variables which represent the lowest quality of resource conditions which may support an activity or function.

Oligotrophic: Low in nutrients.

Optimum: In reference to optimum resource conditions in location criteria, it is the set of data variables which represent the highest quality of resource conditions which may support an activity or function.

Secchi Disc: A disc, with a flat horizontal surface, which is lowered into the water until it is no longer seen. At this point the depth is recorded, which represents light transparency of the water.

Shore Zone: The area around the lake shore which includes the aquatic littoral zone and the terrestrial nearshore, foreshore, and backshore areas. In this thesis the shorezone study area is defined as that area between the deep water edge of the littoral zone and the nearest road to the lake shore.

Suitability: Location criteria and resource data are used to analyze and determine a site's capability to provide for an activity or function. A site may be found to be of optimum suitability, acceptable, minimally suitable or unacceptable in a suitability analysis.

Transect: A line that extends from one end of a study area to the other. Data is collected along a transect to sample an area's resources.

Trophic State: The levels of nutrients in a lake. A lake rich in nutrients is eutrophic and a lake low in nutrients is oligotrophic. Mesotrophic water falls in between the two.