ENGINEERING FEASIBILITY STUDY

FOR

OFFSHORE MOORAGE BUOYS FOR HOUSEBOATS

0N

LAKE BILLY CHINOOK, OREGON

Pelton Round Butte Project

FERC Project Number 2030

For

Portland General Electric Company

And

Confederated Tribes of the Warm Springs Reservation of Oregon

By

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Scope

Lake Billy Chinook is a reservoir in central Oregon and a popular location for recreational boating activities. Houseboats, both rented and privately owned, are widely used. The lake is also popular with anglers, cruisers, and water play enthusiasts. This report will examine, from a technical engineering viewpoint, the feasibility of installing permanent mooring locations for houseboats on Lake Billy Chinook. The information and conclusions herein are current to the date of this report.

Feasibility

To answer the question as to feasibility, it is first necessary to define the exact meaning of feasibility. There are several different types, including technical feasibility, practical constructability, and economic feasibility.

Examination of technical feasibility is first and foremost the primary purpose of the engineering study. Without any reservations whatsoever, in the Engineer's opinion installation of houseboat mooring stations on Lake Billy Chinook is technically feasible. This simple conclusion disregards any consideration of cost vs. benefits.

When other areas of feasibility are examined, the question becomes much more difficult, and the answers less well defined. Cost per houseboat mooring becomes significant to the funding parties, and defines economic feasibility.

Also, practical constructability is somewhat dictated by available equipment, and ability and expertise of installation contractors. Locally available resources generally result in lower project costs. Mobilization and use of large equipment, and globally available personnel, often creates an adverse impact to smaller, low budget projects.

From a strictly engineering viewpoint, moorings for houseboats on Lake Billy Chinook are definitely technically feasible. A far greater challenge to implementation is finding consensus among stakeholders regarding funding, rule-making, and enforcement of rules at the mooring locations.

Lake Billy Chinook Description

Lake Billy Chinook (LBC) is a multi-use reservoir created by the completion of the Round Butte Dam in 1964 by Portland General Electric (PGE). It is an earth and rock fill structure 440 feet high. It is the uppermost, and Lake Simtustus the lower, of two reservoirs utilized by PGE for hydro-electric power electric generation. Lake Billy

Chinook (LBC) is located about 100 miles above the confluence of the Deschutes River with the Columbia River.

The lake has an area of 3,916 acres, and a normal pool elevation of 1,945 feet above sea level. It consists of three long narrow arms of the three rivers which enter the reservoir. They are the Metolius, Crooked, and Deschutes Rivers. The Metolius arm is 12 miles long, the Crooked arm 6 miles, and the Deschutes arm 8.5 miles. There is a total of 62 miles of shoreline. The surrounding topography is arid and steep, with extensive rock outcrops. Maximum depth is 415 feet, and average depth is about 102 feet. The volume is approximately 400,000 acre feet of water. The upstream drainage basin has a total of 7,380 square miles.

Recreational activities are popular at LBC. Cruising, water play, and angling all contribute to heavy use by boaters. A large Oregon State Park, Cove Palisades, is located along the Crooked River and Deschutes arms. The state park has campgrounds, cabin rentals, swimming areas, boat ramps, and a marina. There is also a private resort area and marina mid-way along the Metolius arm, and a U.S. Forest Service campground (Perry South, which in the past was also known as Spring Creek) at the upper end of the Metolius arm. Perry South has a boat ramp and marina docks for overnight tie-up. In addition, there are also privately owned properties along the lake's shorelines.

The Confederated Tribes of the Warm Springs (CTWS) own the reservation lands to the north side of the Metolius arm. The Warm Springs Indian Reservation begins in the center of the Metolius arm river channel, and follows the channel of the Deschutes River beneath the reservoir surface. The Tribes do not permit public access to the shoreline on the north side. One area popular with day-use boaters is an island at Mile 5 along the Metolius arm. Known as Chinook Island, it has good swimming and tie-up docks. The island is part of the lands of the Warm Springs Indian Reservation, and presently the Tribes allow public day use of Chinook Island. No overnight use is permitted.

Site Specific Locations for Feasibility Study

Specific sites were examined for possible installation on up to 50 mooring buoys for houseboats. The sites were determined by the Licensees following consultation and discussion with a large group of stakeholders including land managers and houseboat interests. Locations were chosen to minimize conflicts with owners of private lands, cultural areas, and sensitive environmental areas. Potential sites are identified on all arms of the lake, the Metolius River, Deschutes River, and Crooked River arms. Each site will be examined in detail.

For purposes of uniform identification, each site will be listed by arm, river mile, and left or right side of river channel designated by compass direction (N,S,E,W). A river mile

(RM) is measured from Mile 0.00 at its mouth. River Miles are shown on U.S. Geological 1:24,000 scale, Fly Creek and Round Butte Dam maps. The Deschutes River (DR) originates in the Cascade mountains, flows through Lake Billy Chinook, and continues to its mouth at the junction with the Columbia River. Both the Metolius River (MR) and Crooked River (CR) channels join the Dechutes River Channel within the waters of Lake Billy Chinook, where their respective mile zeroes are located. The MR generally flows west to east, and both the DR and CR generally south to north. A summary of the nine identified sites follows.

(1) MR RM 0.8 N, (2) MR RM 1.0 N, (3) MR RM 1.8 S, (4) MR RM 2.5 S, (5) MR RM 8.5 N, (6) MR RM 9.2 S, (7) DR RM 116.8 E, (8) CR RM 0.4 E, (9) CR RM 2.2 W.

Two small unnamed coves along the north shore of the Metolius are MR RM 0.8 and MR RM 1.0. They are similar in depth and terrain characteristics.

Juniper Canyon joins the lake on the south shore, MR RM 1.8 S. It is large and distinct, with the water surface indented 2,000 feet from LBC's adjacent shoreline. This site is very good from a viewpoint of scenery and privacy, but the steeply sloped terrain would limit development of mooring locations. Just upstream, MR RM 2.5 S, Big Canyon also enters from the south. It is a little smaller than Juniper C., but has similar rugged terrain with limited development opportunities.

Several miles upstream on the Metolius, MR RM 8.5 N, is a large cove. It is on a north outside bend where the Metolius River temporarily bends to the south to bypass a bluff. A large surface area is available for water depths between 50 and 150 feet. The bottom is gently sloped, and the on-shore terrain is rounded and free of rock outcrops. This cove is approximately 1.3 miles west of Box Canyon. Less than a mile upstream, MR RM 9.2 S is a similar cove on the opposite side of LBC. Bottom conditions are favorable. This cove is approximately 0.5 miles from the entrance to the cove leading to Perry South campground in the Deschutes National Forest. Both of these coves are very suitable for development of houseboat moorings.

Along the Deschutes River channel, only one site is identified, DR RM 115.8 E. This site is a large cove within the Cove Palisades State Park. The area is popular for day use, with a swimming area, docks for small boat tie-ups, parking lot and nearby campground. It is adjacent to a very scenic peninsula with unique ecological features, known as The Island, although it is not a true island in the lake. It would be a popular destination for houseboats. Fortunately the site has a large available water surface area, with very gently sloping bottom, which would make an ideal location for houseboat moorings from an engineering point of view.

Two sites have been identified along the Crooked River Arm of LBC. The first is a cove, CR RM 0.4 E, approx. 10.5 miles downstream from the marina area of the Cove

Palisades State Park. The area available is not extensive, but lake depths and bottom conditions make this site suitable for moorings.

The other site along the Crooked River, CR RM 2.2 W, is adjacent to the east side of The Island peninsula area, and within the Cove Palisades State Park. There is a large water surface available with good bottom conditions. There would be little chance of conflicts with other recreational boaters, as the lake narrows and there is minimal upstream activity. Roads on both sides of the Crooked Arm may limit this site from a scenic and privacy view, but engineering feasibility is good here for houseboat moorings.

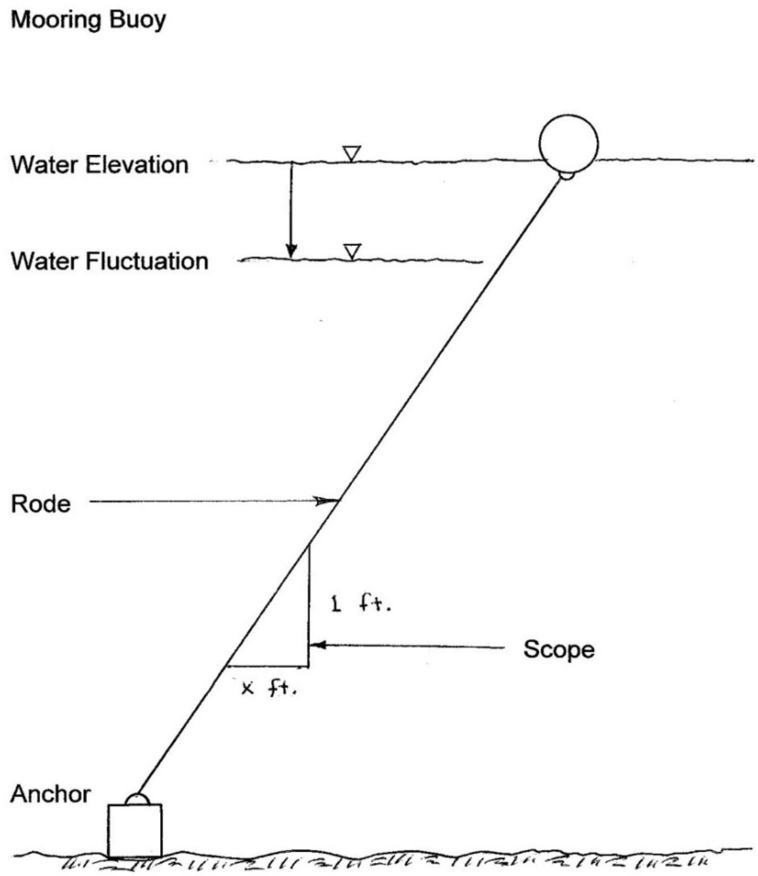
Design Criteria for Houseboat Mooring Stations

In order to determine engineering feasibility of mooring stations for houseboats, it is first necessary to determine criteria upon which the design should be based. Houseboat size and season of use is of primary importance. <u>For purposes of this study, the "design houseboat" was established by the Licensees at 60' long and 44,000 pounds empty, and 16' wide x 15' high.</u> Loaded weight is therefore estimated at 52,000 pounds.

The second critical criterion is amount of water level fluctuation, which extends into a consideration of the desired season of use. Water level is managed to a near constant during the summer season of houseboat use on LBC. Only <u>one foot</u> of variation in water elevation is to be considered in order to determine engineering feasibility of houseboat mooring locations.

Moorage Station Defined

A mooring location for the tie-up of boats is fixed in position, by attachment to the bottom of a water body. There are basically three parts of a mooring. They are the anchor, the rode, and the floating surface marker. The rode is the chain, rope, cable, and/or other devices which connect the anchor to the buoy floating at the surface. Boat operators tie-up at the buoy. The following diagram shows a typical mooring location.



Components of a Mooring System

Design Considerations - Forces on Houseboats

Boats at anchor are subject to the three major forces of current, wind, and waves.

For the lake situation, there are no current forces.

Wind directions and velocity data are available from the National Weather Service, local airports, military agencies, and building codes. The wind speed should be adjusted for local conditions to obtain wind speeds that are representative and applicable for specific sites. The selected wind speed should have rational merit, and some consideration of risk analysis is in order. There is little need to design for a maximum peak wind gust which may not occur for another 100 years, when such a design basis may grossly affect the economics of the project. If such a peak wind should occur, there is a potential for some damage, but the cost of protection would destroy the project's economic feasibility. Seasons of use and location of moorages are mitigating factors which require a considerable amount of engineering judgment in the application of loads

In the sheltered coves and near-shore locations under study for houseboat moorages on LBC, winds in excess of 80 miles per hour are not anticipated.

The commonly accepted formula horizontal for wind forces on boats is expressed in metric units, with force in Newtons (1 Newton=0.225 pounds).

F = 0.72 (E x D x S x V squared)

E = Boat end area, in meters squared
D = Direction factor
S = Shielding factor
V = Terrain air velocity in meters per second (1 mph = 0.447 m/s)

For the isolated houseboat mooring locations, the shielding factor is negligible. It is intended for use in marina situations. But the direction factor is important. With a boat rotating with the wind, attached to a mooring buoy, one would expect the end area would be the wind exposure area. However, modern boats, with their wide width (beam) to length ratios, and also particularly houseboats, tend to wander a little back and forth when the wind blows. This exposes the area of the boat's side to the wind, at some angle. The direction factor accounts for this and increases the force above that which would be applied if only the end area were considered.

<u>Application of the above formula to the LBC design houseboat yields a wind force of 4,850 pounds acting horizontally on the boat.</u>

A fetch is the distance along the lake the wind can blow in a more or less straight line. Wave heights are dependent on fetch distance and become greater as they travel downwind. In the sheltered coves and near-shore locations under study for houseboat moorages on LBC, waves in excess of one and one-half (1 ½) foot height are not anticipated. Due to the low water fluctuation in LBC and the weight of the mooring buoy anchor chains or other materials (rode, the sag in the rode's catenary will provide more than enough slack to absorb the cyclic wave forces without a significant increase in the force on the bottom anchor. For the purposes of this study, wave forces will be considered negligible for houseboat moorage locations on LBC.

Design Considerations - Area Required for One Houseboat Moorage

In order to estimate the total number of potential houseboat moorage sites available, the area required to anchor one houseboat must be determined. It is recommended the minimum distance from shoreline be 100'; that no part of the houseboat under any loading condition should be within 100' of shore.

With a recommended single mooring buoy, and the houseboat rotating with wind and waves, the minimum diameter of one houseboat moorage area would be approx. 125' with essentially no wind (two houseboat lengths plus buoy). With a single bottom anchor, in 100' of water depth, and the recommended 400' long anchor rode, the diameter of the area required for one houseboat would be approximately 900', and the houseboat could swing 1,000' off-shore toward the center of the lake channel. That is a traditional design for open waters, but at LBC such a solution would conflict with other boaters and require too much space to be a practical solution.

To greatly reduce the water area required for each houseboat moorage, a two point anchoring system could be used for each buoy to hold them in relatively fixed position, although the buoy will still move a certain amount under strong wind loads. That movement will also create a diameter; that of the maximum movement of the mooring ball under strong wind conditions. Movement of the mooring ball is never expected to exceed a circle 140' in diameter, and that is a conservative value for maximum load conditions. The total diameter of a single mooring circle, in 100' depth of water with a 400' long anchor rode, would then be only 200', reasonable in terms of areas available and size of LBC. In other words, it is recommended that the minimum spacing between mooring buoys be 200' center to center, and the buoys should be placed 200' offshore.

Design Considerations – Preliminary Engineering Design for Houseboat Moorage

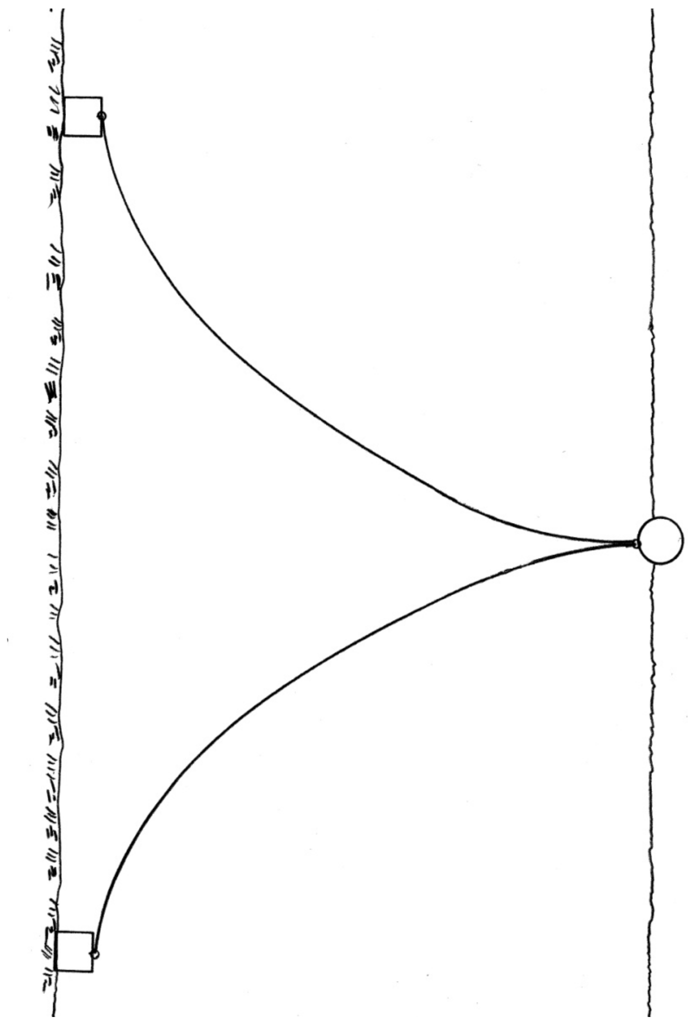
Anchors are critical components of mooring points. Several types of anchors are used, depending on conditions and design requirements. Most are gravity type dropped into place. They are constructed of concrete or metal, and many or shaped to embed into the bottom to provide additional resistance. Common metal types include mushroom and danfort anchors, which embed similar to an anchor on a large ship. Underwater piling, driven or drilled into place, is used to provide much greater resistance to uplift force. Underwater sections of piling if often used to anchor entire marinas or other high value installations, where minimal movement of the marina is required. When the fixed anchors are used, it is possible to use a much steeper scope of the rode lines. With gravity type anchors, a flatter rode scope is used to reduce anchor uplift force. Presently no piling exists on Lake Billy Chinook. The presence of extensive rock prohibits pile driving, and drilling is cost prohibitive for the size and types of facilities on LBC.

The rode connects the bottom anchor with the floating buoy. Rodes are fabrications of chain, cables, ropes, and Seaflex. They can be entirely of one kind of material, or combinations of multiple materials. The horizontal load forces to the mooring buoy are transferred to the bottom anchor by the rode, through tension force. Selection of the rode design requires careful consideration. Under a conventional scenario, the horizontal force at the surface and the rode hangs downward from the buoy due to the weight of the rode, and the tension force in the rode ultimately becomes a horizontal force applied to the bottom anchor. This is technically possible because the due to the rode's weight it does not follow a straight line, but hangs in a catenary shape underwater. A catenary is the curve assumed by an inelastic flexible cord hanging between two points. Due to this effect, careful rode design will create the most beneficial condition for the holding power of the bottom anchor. Length of the rode, which determines its scope or bottom angle, is of major importance with conventional designs.

Since anticipated bottom conditions are not favorable for piles or other anchors fixed to the bottom, a large weight is the obvious choice. The bottom is either rocks, or rock under an unknown but assumed small amount of overburden. The anchor rode, with its length, applies mostly horizontal force and tries to drag the anchor along the bottom. Bottom resistance to dragging is provided by the overburden and/or uneven rocks. There is also a small vertical lifting force component on the anchor. Large horizontal and small vertical forces are desired, which can be obtained through careful consideration of anchor rode length and weight. Reinforced concrete anchor weights likely would be constructed on-site. For comparison purposes, commercially obtained large concrete blocks are used for highway retaining walls and are readily available. The common name is ultrablock, and a typical block is 2.5' x 2.5' x 5' and weighs approximately 4,320 pounds in air. It is important to remember that all materials have a buoyancy factor, equal to their volume less the density of water at about 62.4 pounds per cubic foot. A 4,320 weight in air only weighs 2,520 pounds underwater. For increased weight, multiple anchor weights, chained together, may be placed at one location.

The rode connects the bottom anchor to the surface mooring buoy. Longer rodes increase the holding power of the bottom anchors. Common materials used for rodes are chains, wire rope, and synthetic rope, and combinations thereof. A typical design would be a length of heavy chain from the anchor, then a length of lighter chain, and short length of heavy chain at the buoy to prevent interference of rode with boat propellers. Proof coil chain should be used, and is available hot dip galvanized. Recommended chain sizes are 1', ¾", and ½". The working load limit of a ½" proof coil chain is 4,500 pounds, but the weight is 270 pounds per 100 foot length which requires the mooring buoy to support a lot of weight. Additional submerged buoys can be used to support part of the rode weight, but that approach increases installation cost and complexity. Synthetic ropes are just as strong much lighter and therefore much easier to work with during installation. The use of synthetic rope for rodes is increasing as there are not subject to the corrosion/damage potential of wire rope or the wear characteristic of chains.

Boats at anchor are attached to the floating buoy, which marks the location of the moorage. Large mooring buoys are available and should be used to support the weight of the anchor rodes. The large buoys also provide a high degree of visibility for other boaters on LBC, when they are not occupied by houseboats. Recommended buoy size is 42 inch diameter with a buoyancy rating of 1,320 pounds.



TWO POINT ANCHOR SYSTEM

Reduces Movement of Buoy and Minimizes Water Space Required

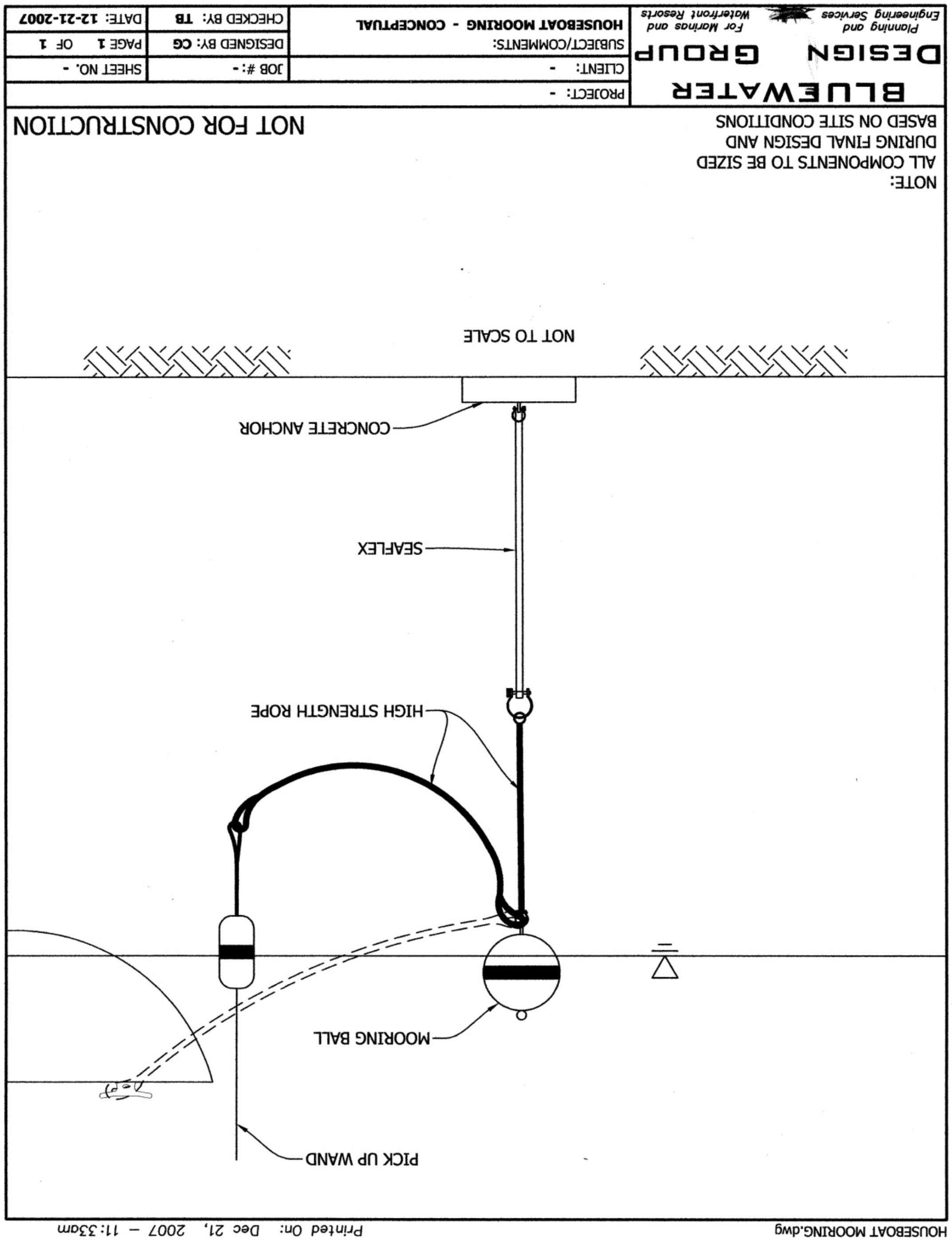
Alternative Design with Seaflex

Seaflex is a word becoming more common in the U.S. marine industry. In simple terms, it is an elastic rubber product although much more complicated than that. Seaflex originated in Sweden, and installations in Europe have been in place for 27 years. The product is exceedingly strong and can elongate under increasing loads up to two times its original length. It is used in anchor rodes, and acts as a giant shock absorber to significantly reduce the forces of winds, waves, and currents at their point of application to the bottom anchor.

Anchor systems using Seaflex have been in use for about 15 years in the U.S. Due to the increasing market, the company maintains one Swedish representative in North America to assist with product use and import/distribution of the Seaflex. His name is Kent Johansson and he is currently stationed in Florida. Mr. Johansson has been consulted in the preparation of this report. The Oregon State Marine Board has used Seaflex as part of the anchor rodes for all 20 of the State's floating restrooms. There have been no failures, and the product performs exactly as the manufacturer claims. There are no known equal products.

Seaflex anchor systems have a number of advantages over conventional systems with long heavy rodes which rely on the catenary sag to adjust to cyclic forces. Due to the elongation characteristic of the Seaflex, lighter rodes of much shorter length may be used. Synthetic rope is commonly used for the major portion of the rode. Only one anchor point and one rode is required with a Seaflex system to maintain the mooring buoy at a relatively fixed mooring location, which is required to reduce water surface area for each mooring buoy. This results in an anchor system which is cost effective, easier to install, and in the author's opinion superior to other anchor methods. Use of Seaflex should be aggressively pursued during final design of mooring buoys proposed for installation at Lake Billy Chinook.

A drawing showing a typical Seaflex anchor system for a single mooring buoy is shown below.



A mooring system which utilizes Seaflex in the design requires one anchor point. Elastic cables elongate under loads, with increasing resistance. This unique, time proven product allows for fluctuating water levels and keeps the buoy in reasonably accurate location.

Floating Restrooms in the State of Oregon

The Oregon State Marine Board (OSMB) is Oregon's recreational boating agency, and provides a major facilities grant program to public agencies for construction of boating facilities. One portion of the grant program allows funding of floating restrooms. During the last 15 years, twenty floating restrooms have been installed statewide. With the exception of two in Tillamook Bay, the other 18 are installed in lakes and reservoirs.

The restrooms are large barge-like aluminum boats, with a restroom building attached. The restroom contains two toilet stalls and a mechanical room. OSMB provides the engineering and construction assistance to anchor the restrooms in place. The floating restrooms are held in place by two anchor cables, one opposite each end of the restroom. A relatively simple anchoring system has been developed, using concrete dead-man anchors, which are deployed manually from the restroom structure, without the use of additional equipment. This system has a proven track of reliability for 15 years, and has been used in locations with seasonal water level variations excess of 50 feet, and anchored in depths up to 150 feet. Installed locations include State Parks reservoirs at Prineville (two), Lost Creek, Owyhee, and Lake Billy Chinook (three).

Oregon's floating restrooms have many features similar to houseboats, including shape, size, and weight. Although the dry weight is 12,000 pounds, they contain two 1,000 gallon ballast tanks which are filled during installation to provide increased stability. They also contain a 1,000 gallon sewage holding tank. Thus the total installed weight of the loaded restroom is 37,000 pounds. The floating aluminum barge is 12' x 24', with a 4' x 7 ½' x 14' restroom building placed on top. Two anchor rodes are used, and the restroom does not rotate with wind direction, so the wind force is applied to the 71/2 x 14' surface.

The anchor weigh is in the shape of a cylinder and weighs 1,885 pounds dry, which is 1,106 pounds underwater when the buoyancy effect is included. Two of these weights, chained together, are used at each anchor location. Two anchor location are used, one opposite each end of the restroom. When wind and wave loads are applied, a total underwater weight of 2,212 pounds at each anchor point holds the floating restrooms in place.

The rodes are primarily galvanized, plastic coated wire rope, but a key component is a section of Seaflex, a Swedish product which elongates under load up to double its length, with increasing resistance. The Seaflex component allows the rodes to adjust to changing water levels without creating slack in the rodes. This holds the restroom in close proximity to the desired location. More importantly, Seaflex is able to absorb short duration loads, such as wind gusts, and greatly reduce the maximum load force on the anchor. The usual scope of the rodes is 1 vertical to 3 horizontal, but some locations are as steep as 1 vertical to 2.5 horizontal.

.Existing State Park Moorages for Houseboats on Lake Billy Chinook

The Oregon Parks and Recreation Department installed six houseboat moorage buoys approximately 10 years ago within the boundaries of The Cove Palisades State Park. Four are on the Deschutes River Arm, and two are on the Crooked River Arm. They are bottom anchored by concrete weights, but no records exist concerning the details of the installations. Information has been obtained from houseboat rental vendors, park personnel, and visual observations by the Engineer. Two or three weights, apparently spaced a relatively short distance apart, are each connected by a chain to the buoy. Two weights on-shore, similar to those thought to be used as anchors, weighed 1,150 and 3,800 pounds in air, as estimated from field measurement of size. The existing State Park moorages appear to have been constructed without much careful analysis or record keeping, but have been in successful operation for a number of years with minimal difficulties. <u>This has considerable significance when considering feasibility of houseboat moorages on LBC, because houseboat moorages are already are in existence.</u>

Houseboat Moorage in Other States

Many other states have large numbers of houseboats on very large lakes, and permanent houseboat mooring stations are not uncommon. One location of particular interest is Dworshak Reservoir near Lewiston Idaho at a state park. They have six individual moorage locations in a lake with water level fluctuations up to 155’ and depths to 450’. The design boat was a 60’ houseboat, the same as LBC feasibility study. They used a concrete gravity anchor, chain and wire rope for the rode, and an underwater (20’ depth) buoy to support most of the heavy weight of the rode, and a surface mooring buoy. There is an underwater forest at the lake bottom. They have had a number of problems during the three year period of use, and most likely would not use this design again. The submersible buoy was not large enough or strong enough. The initial surface buoy (24” diameter) was not large enough to support its portion of the rode. At full pool lake elevation, the chain/cable rode was almost directly over the anchor weight, and the required holding capacity could not be met. To alleviate this problem, they add lengths of cable to the bottom of the buoy, and then remove as the water recedes to prevent the slack from getting tangled in the submerged buoy or submerged trees, which is a labor intensive process. The required anchor force in the installation contract was 10,300 pounds, calculated from an 80 miles per hour wind action sideways on the houseboat. The concrete anchor weight used was 4,000 pounds. The contract agency was the U.S. Army Corps of Engineers (USACE), and Idaho State Parks and Recreation took over operations as an out grant. The contract cost for six buoys was

$88,044.00, and in addition the USACE provided barges as floating working platforms for contractor's installation activities.

The author of this feasibility report has several opinions and comments regarding the Dworshak houseboat mooring stations. Many of the stated problems would likely have been reduced by a more careful design. The moorage force of 10.300, acting sideways to the houseboat, is not realistic and excessive for a single mooring buoy where the boat pivots with the wind. Likewise, the 4,000 pound anchor appears much too small for the required force. In addition, mistakes were obviously made in size of the buoys and scope of the anchor rode at full pool. Also, the project cost per mooring buoy was very high. Note that the design requirements, with 150' water fluctuation on Dworshak Reservoir, were much more severe than the design requirements at Lake Billy Chinook. The author greatly appreciates the information and thoughtful, after the fact, objective analysis provided by Paul Pence, USACE Natural Resources Manager at Dworshak Dam and Reservoir, and Kristi Stephens, Park Manager at Dworshak State Park.

Installations in other states have been reviewed. Most locations in Florida and Washington are in shallow waters, and where large equipment is available. The preferred method is to drive bury, or auger an anchor point into the bottom surface. This produces an extremely strong anchor point with major resistance to uplift forces. This solution is not realistic in Lake Billy Chinook, due to depths, bottom condition, and location factors.

But houseboat moorage is also very common in Lake Powell in Arizona and other major western impoundments, where the houseboats are much larger and more numerous that those at LBC.

Installation Cost Estimates

Cost estimates based on feasibilities are difficult and very approximate at best. They do help to provide an order of magnitude to assist with future planning and budgeting as project scopes and designs become more firmly established. With that thought in mind, it is doubtful any moorage installation could be built for under $7,500. It could also be anticipated the construction cost of a single moorage would not exceed $25,000. The number of moorages constructed in one project and the availability of floating equipment on LBC will have a significant impact on the cost per moorage.

One important engineering issue will be the method of deployment of the bottom anchors from a floating work platform. However, it should be noted the Oregon State Marine Board engineers routinely simultaneously launch two 1,880 pound (in air) concrete anchors, chained together, from the deck of a floating restroom, by hand power using a long wood lever. Larger anchors could be transported to the work site by work barge of sufficient size, or suspended below a floating platform (weight underwater is 59% of weight in air) and towed into position to drop to the lake bottom.

Maintenance and Inspections

Marine installations such as moorage stations are designed for long life with little need for periodic maintenance and inspections. Designs similar to that suggested in this report should have a useful life in excess of 20 years. The fresh water environment of Lake Billy Chinook, as opposed to sea water, will also help to extend the life of the system. Depending on details of final installation plans, inspection of the anchoring system by divers should be considered on a 7 year interval. Wire rope or chain rodes, depending on the amount of use under wind loads, may wear and require replacement within 10 years. If synthetic rope rodes are used, their useful life could exceed 20 years.

Summary of Recommendations

Nine potential locations were studied for houseboat moorage at Lake Billy Chinook. All sites are suitable for one or more houseboat moorage locations. From an engineering viewpoint, houseboat moorage is most definitely technically feasible in LBC. It was not difficult to find numerous suitable locations for houseboat moorage. A total of 60 feasible houseboat moorage buoy locations have been identified in this report.

Location	M0.8N	M1.0N	M1.8S	M2.5S	M8.5N	M9.2S	D115.8S	C0.4E	C2.2W	T
Metolius R.	1	1	4	2	14	12				34
Deschutes R.							7			7
Crooked R.								7	12	19

No part of the houseboat should be within 100’ of shoreline. Water depths range from 50 to 150’ at mooring buoy locations. Most depths are 80’ or less. Mooring buoys should be spaced at 200’ intervals, center to center. A two point anchor system could be used, and would consist of heavy single or multiple concrete weights, connected by chains or wire rope to the mooring buoy. Length of the connecting rode should be a minimum length of four times the depth of the water at the site if a chain rode is used. Alternative design, using the Seaflex product with synthetic rodes is recommended for the final design. The Seaflex system is recommended due to ease of installation, cost effectiveness, and past history of successful systems installed in Oregon. Only one anchor point is required.

A gravity type concrete anchor should be used. With the estimated maximum horizontal surface force just less than 5,000 pounds, weight of anchor required is anticipated to be approximately 12,000-14,000 pounds in air.

Previous Studies and Information

Some previous published reports and other unpublished reviews have already been accomplished regarding houseboat moorage at LBC. They have been reviewed, and the contents have been considered in the preparation of this report. They are listed below.

The Spatial Distribution of Water-Based Recreation at Lake Billy Chinook and Lake Simtustus, Pelton Round Butte Hydroelectric Project, FERC 2030, by Troy Hall and Bo Shelby, April 1998.

Location and Conditions of Shoreline and Upland Dispersed Recreation Sites Within the Pelton Round Butte Project Area, FERC 2030, by Troy Hall and Bo Shelby, April 1998.

Houseboater Survey Results, FERC 2030, by Troy Hall, PhD, and Bo Shelby, PhD, October 1999.

Unpublished electronic mail and other technical information provided by Christine Foster, PGE Engineering Staff, 2005, regarding some initial houseboat moorage reconnaissance work.

Unpublished electronic mail and other technical information provided by Chad Croft, PGE Engineering Staff, 2007, regarding on-site review with contractor representatives and other initial houseboat moorage reconnaissance work.

References

Atlas of Oregon Lakes, by Daniel M. Johnson, Richard R. Peterson, D. Richard Lycain, James W. Sweet, Mark E. Neuhaus, & Andrew L. Schaidel, Oregon State University Press, ISBN 0-87071-343-4.

Marinas and Small Craft Harbors, Second Edition, by Bruce O Tobiasson, P.E. and Ronald C Kollmeyer, Ph.D., 2000, ISBN 0-9675437-0-3.

Layout and Design Guidelines for Recreational Boating Facilities, Oregon State Marine Board, March 2003.

Topographic Maps, U.S. Geological Survey, 1:24000 Scale, Round Butte Dam Oregon 1992 and Fly Creek Oregon 1962

Personal Conversations

Jeff Smith, P.E., and Raymond Lanham, P.E., Senior Engineers, Oregon State Marine Board.

Kristi Stephens, Park Manager, Dworshak State Park, Idaho Department of Parks and Recreation.

Paul J. Pence, Natural Resources Manager, Dworshak Dam and Reservoir, U.S Army Corps of Engineer, Idaho.

Bill Crawford, Parks Supervisor, Oregon Parks and Recreation Department.

Darryl Fitzwater, Park Manager, The Cove Palisades State Park.

Tim Bazeley, P.E., President, BlueWater Design Group, San Pedro, California.

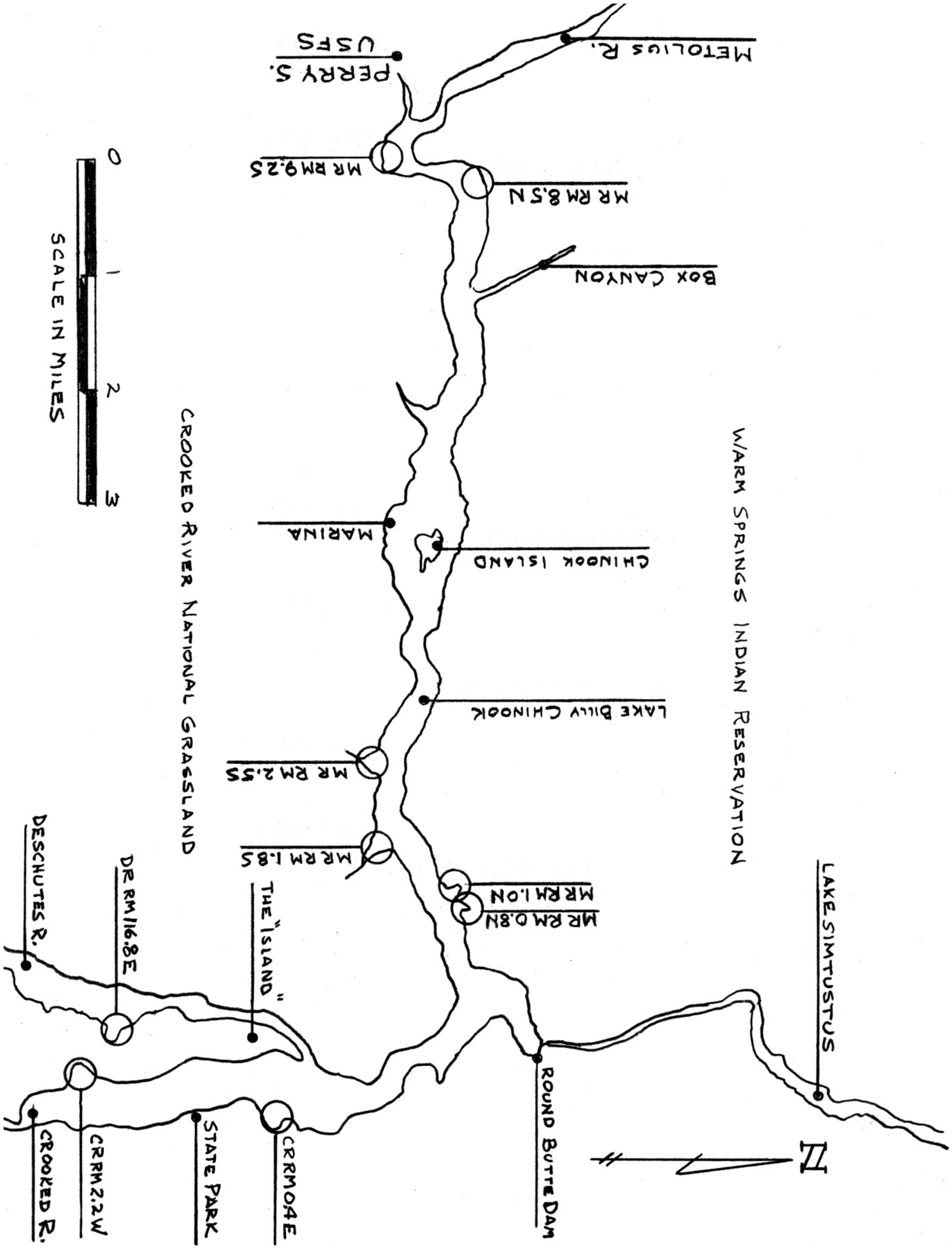
Kent Johanssen, North America Seaflex Representative, at a meeting in Naples, Florida, December 5, 2007.

Appendix

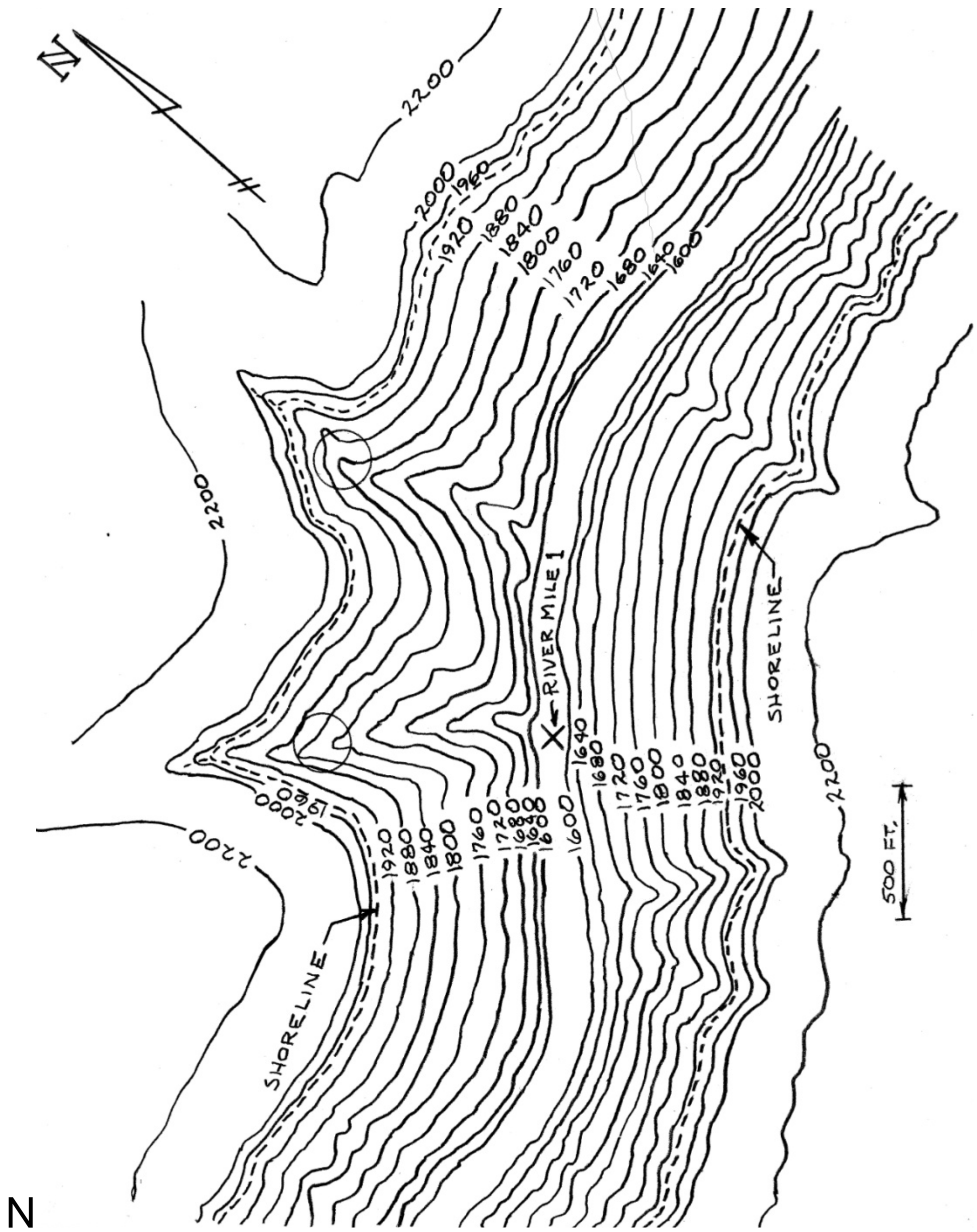
Individual Site Drawings of Nine Study Locations

Seaflex Buoy Technical Information

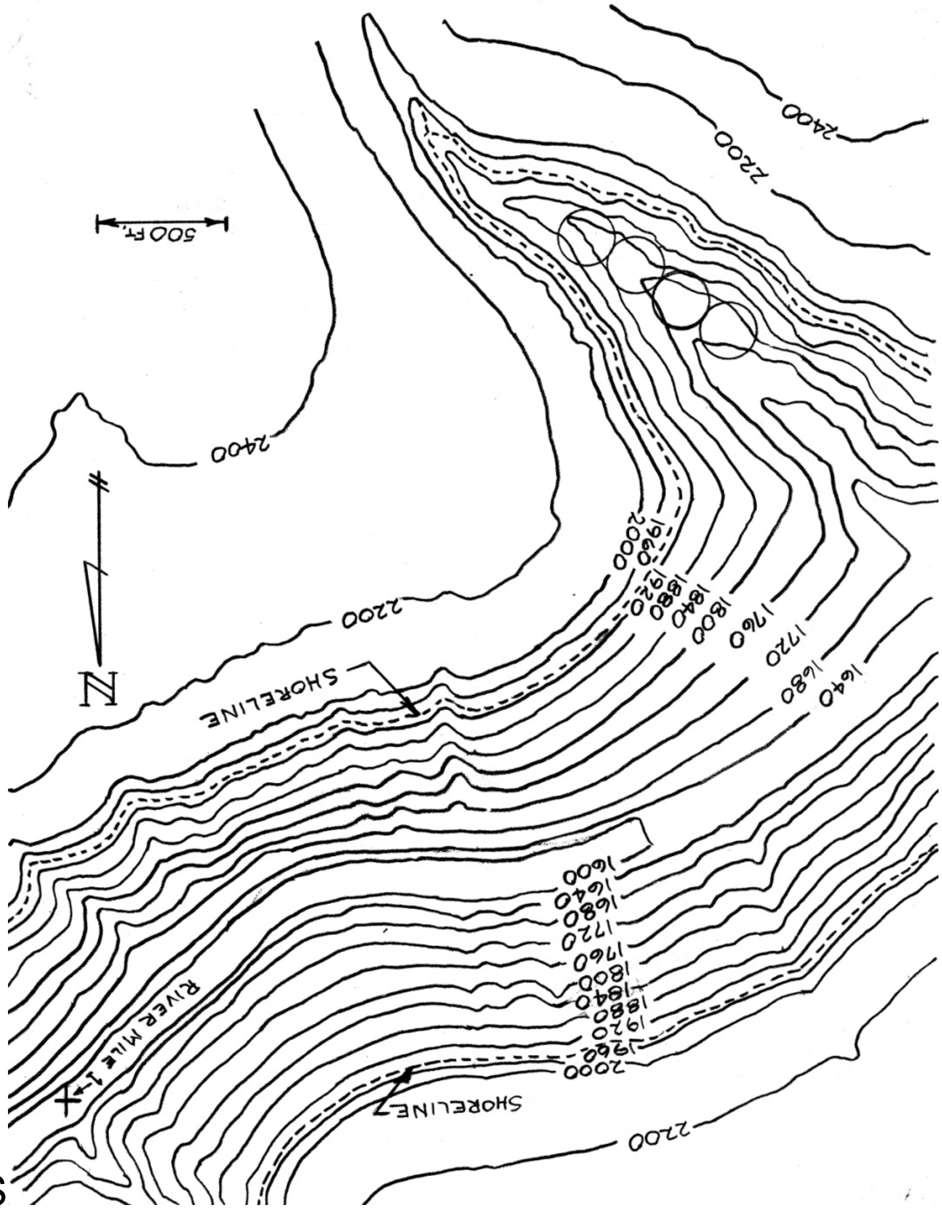
Typical Terrain Photos


METOLIUS R.
PERRY S.
USFS
MR RM 9.2S
MR RM 8.5N
BOX CANYON
SCALE IN MILES
0
1
2
3
WARM SPRINGS INDIAN RESERVATION
CROOKED RIVER NATIONAL GRASSLAND
MARINA
CHINOOK ISLAND
LAKE BILLY CHINOOK
MR RM 2.5S
MR RM 1.8S
MR RM 1.0N
MR RM 0.8N
LAKE SIMTUSTUS
DESCHUTES R.
DR RM 116.8E
THE "ISLAND"
ROUND BUTTE DAM
N
CROOKED R.
CR RM 2.2W
STATE PARK
CR RM 0.4E

MR RM 0.8 and 1.0



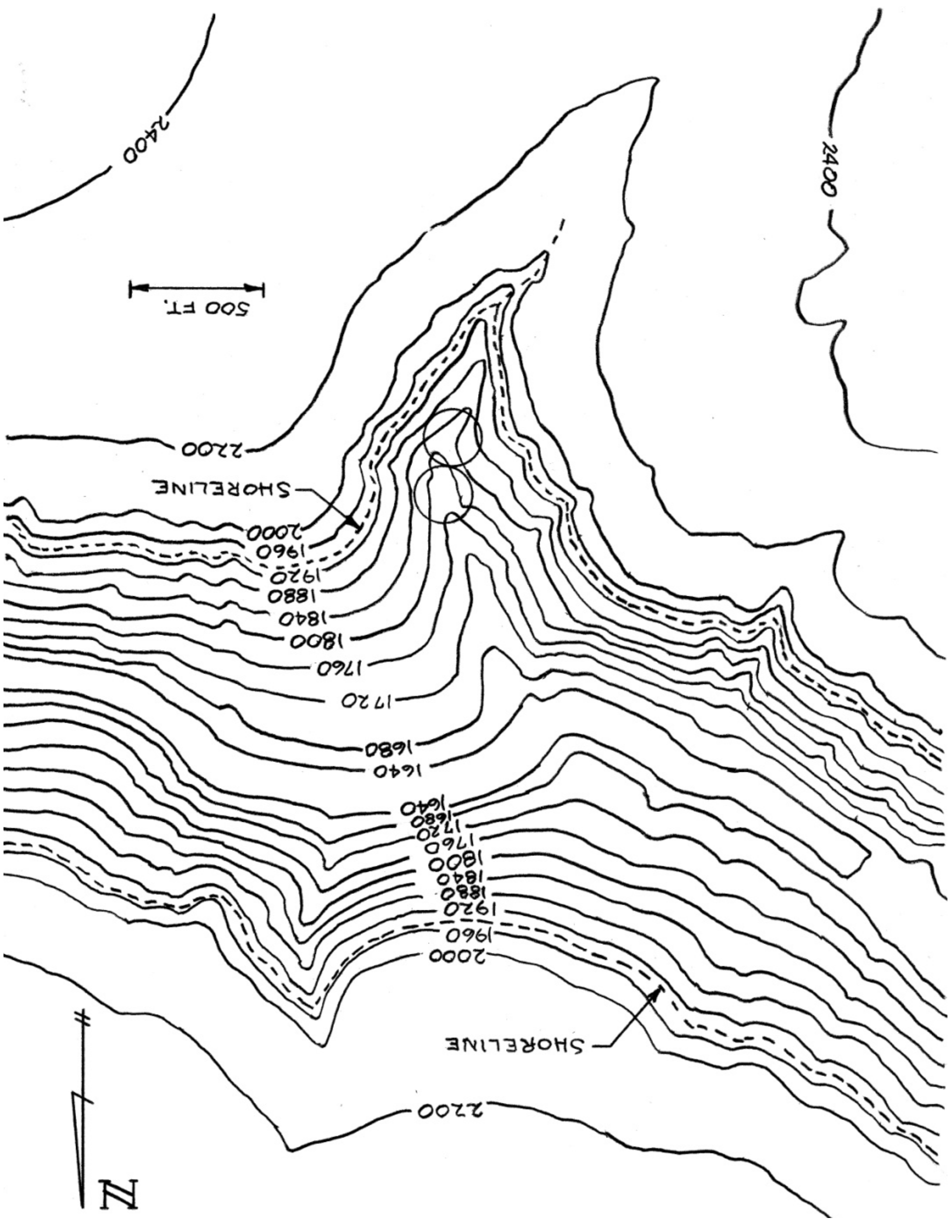
Approximately one mile upstream on the Metolius Arm from the confluence with the Deschutes Arm, two unnamed coves on the north shore offer a desirable location for houseboat mooring, but the terrain is rugged and the underwater slopes are steep. The lake is approximately 350’ deep in the center. Only one mooring buoy is feasible in each cove, and each will provide a private, secluded location.



MR RM 1.8 S

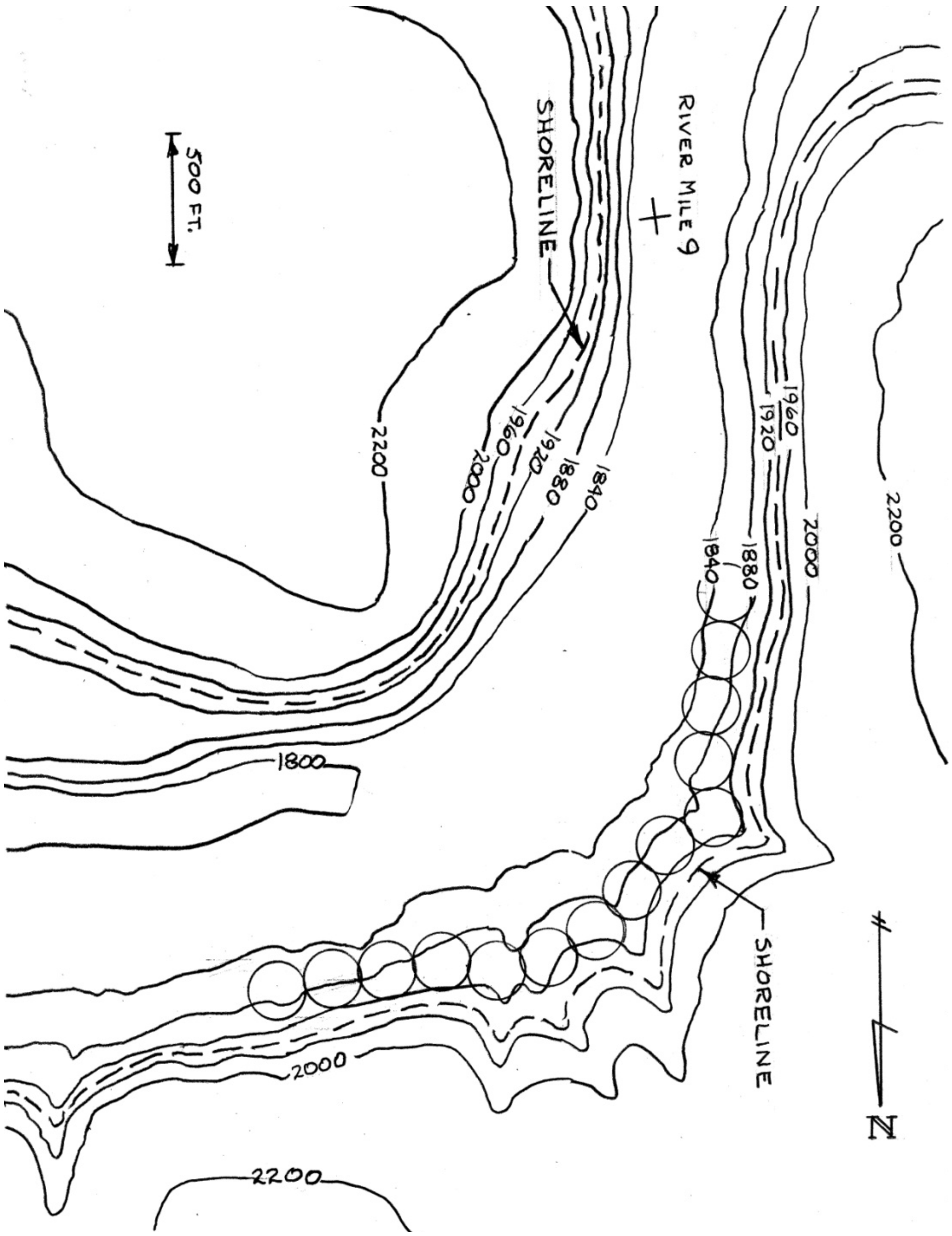
Juniper Canyon is large and enters from the South. It is scenic and has more favorable bottom conditions than nearby Box Canyon, as there is a much greater surface area with reasonably good depths and bottom slopes. Four mooring buoys would be feasible in this protected cove.

MR RM 2.5 S



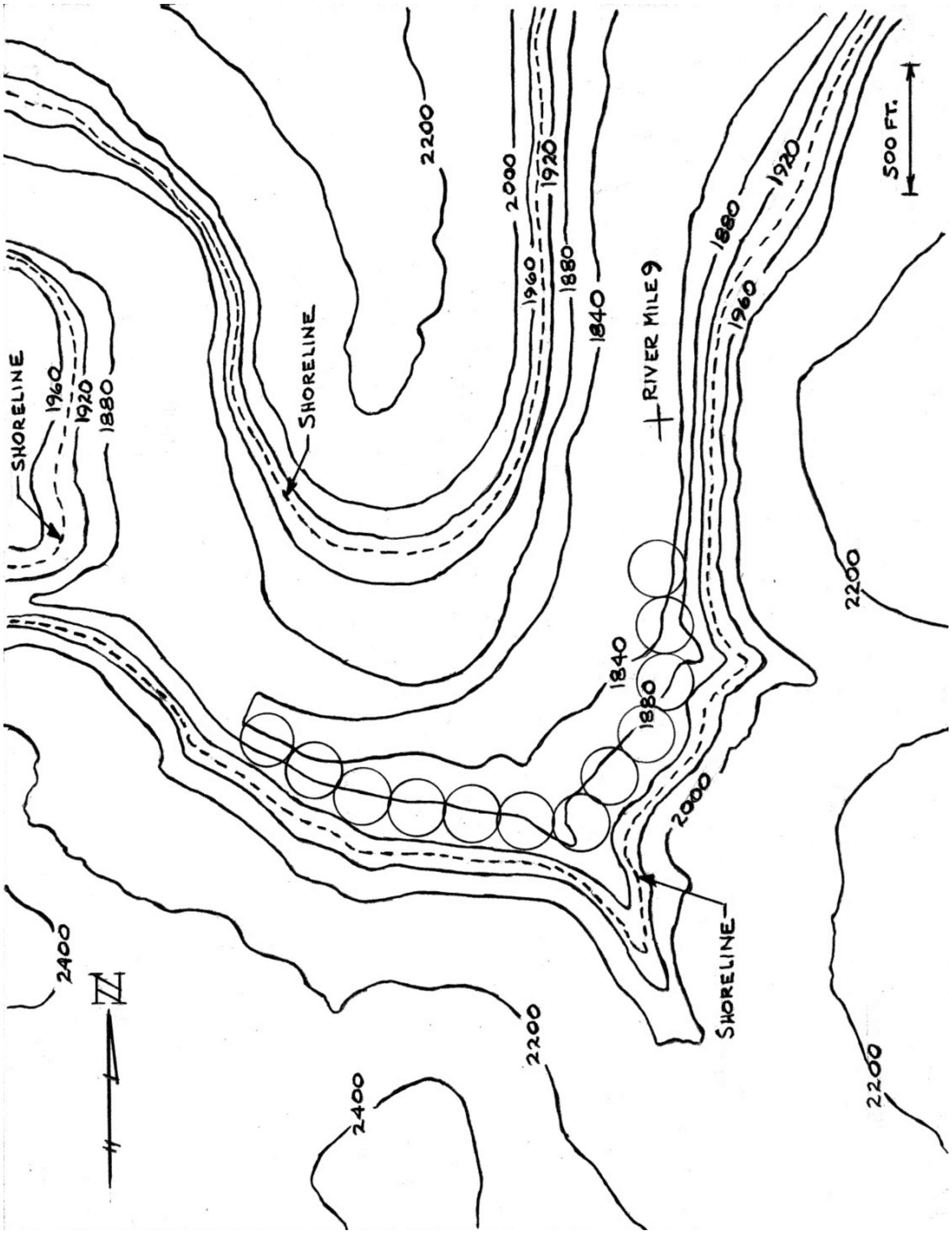
Big Canyon is a large canyon entering from the south. It has a steeply sloping bottom and lake depths go to 300’ in the center. Two mooring buoys are feasible. More could be obtained by anchoring in water depths of 200’ or more, but would require long anchor rodes and be more costly.

MR RM 8.5 N



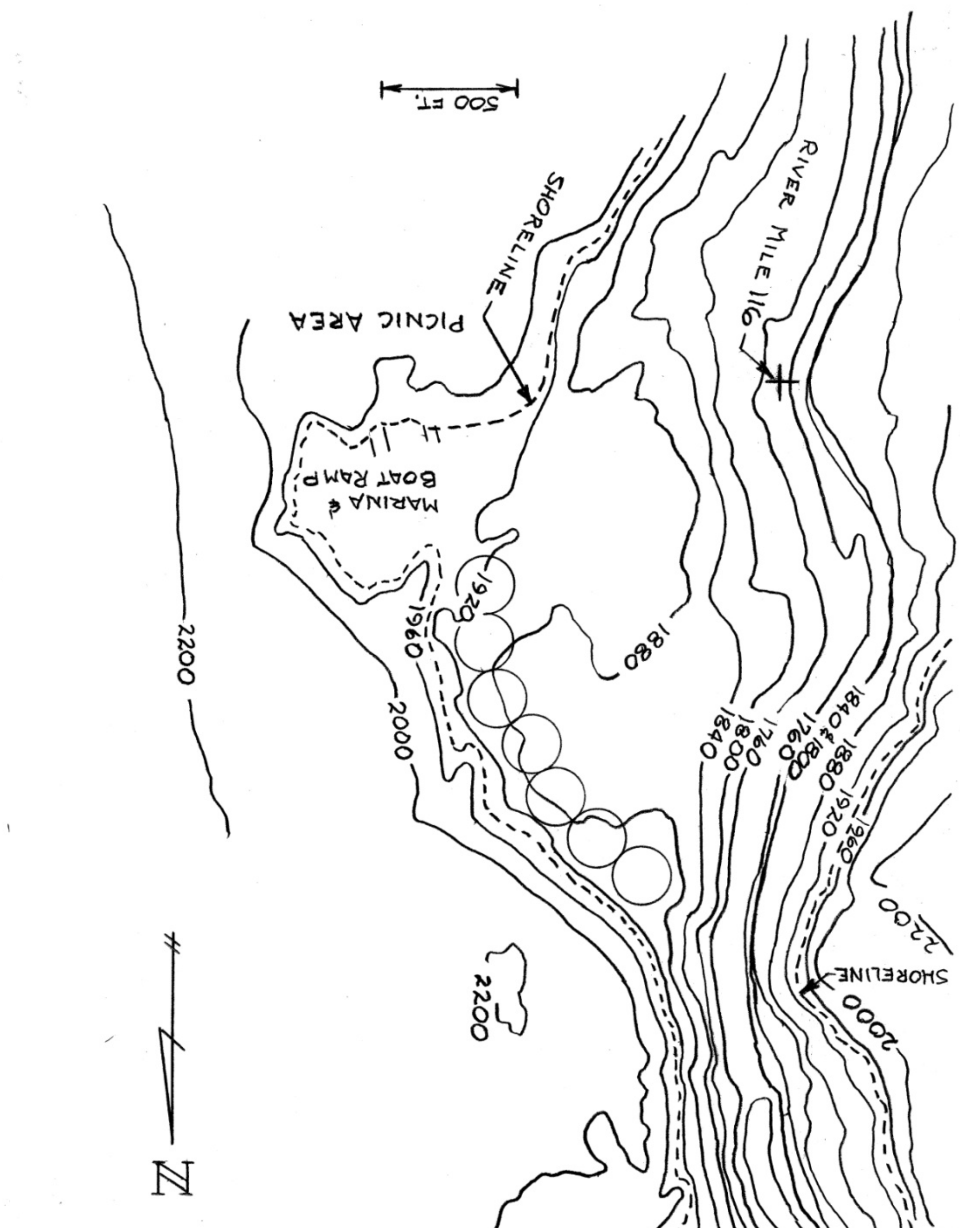
Several miles upstream on the Metolius from the last previous site is a large cove. It is on a north outside bend where the Metolious River temporarily bends to the south to bypass a bluff. A large surface area is available for water depths between 50 and 100 feet. The bottom is gently sloped, and the on-shore terrain is rounded and free of outcrops. The cove is approximately 1.3 miles west of Box Canyon. It is well suited for houseboat moorage locations, and out of the way of other boat traffic on the lake. Fourteen mooring buoys are feasible at this location.

MR RM 9.2 S



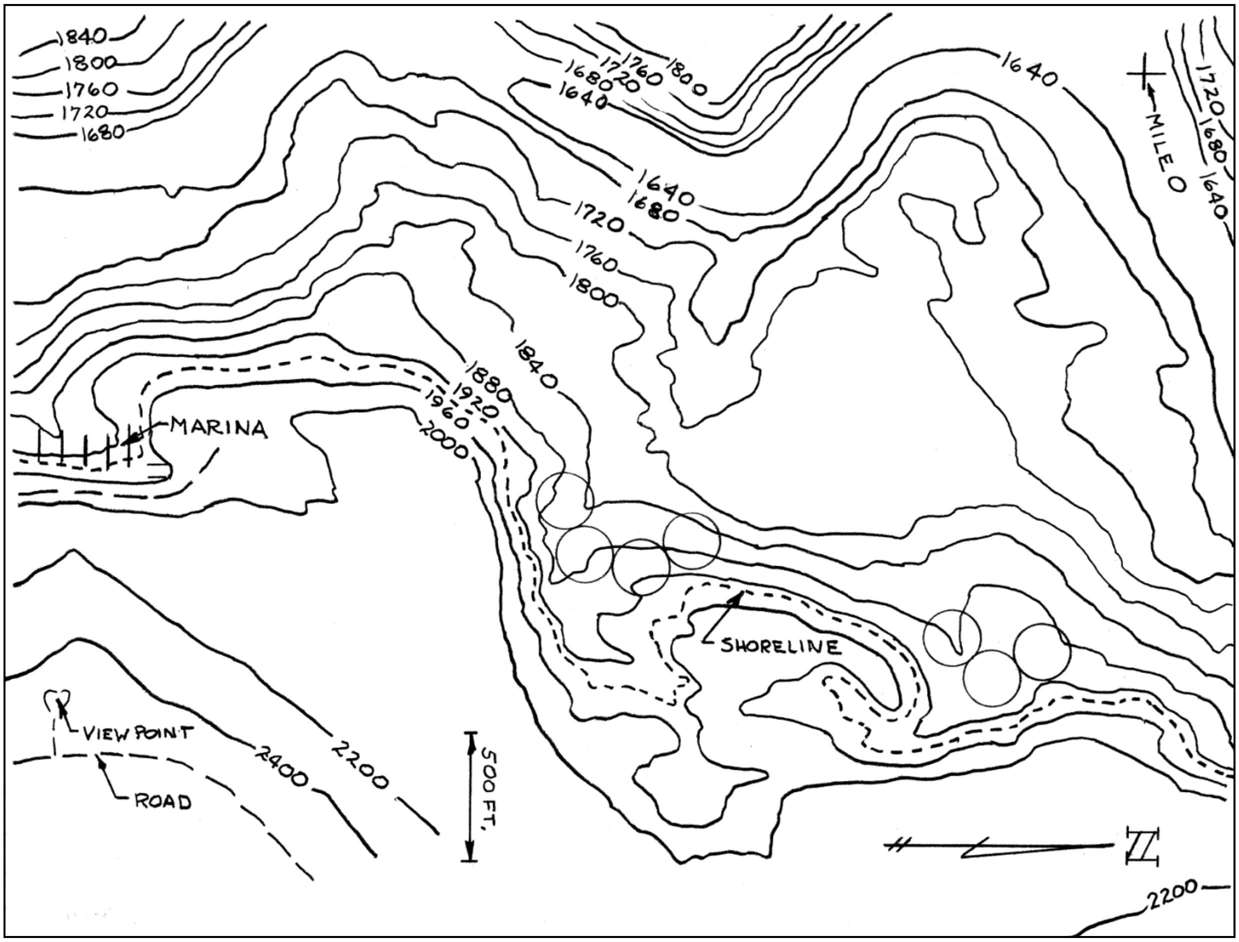
At Metolius River Mile 9.2 there is a large cove on the outside of a turn in the river channel. The lake narrows both upstream and downstream, making this site ideal. A large surface area is available for water depths between 50 and 100 feet. The bottom is gently sloped, and the on-shore terrain is gently rounded and free of rock outcrops. Bottom conditions appear to be very favorable. This cove is approximately one-half mile from the entrance to the cove leading to Perry South Campground in the Deschutes National Forest. Twelve mooring buoys are feasible in RM 9.2 cove.

DR RM 115.8 W



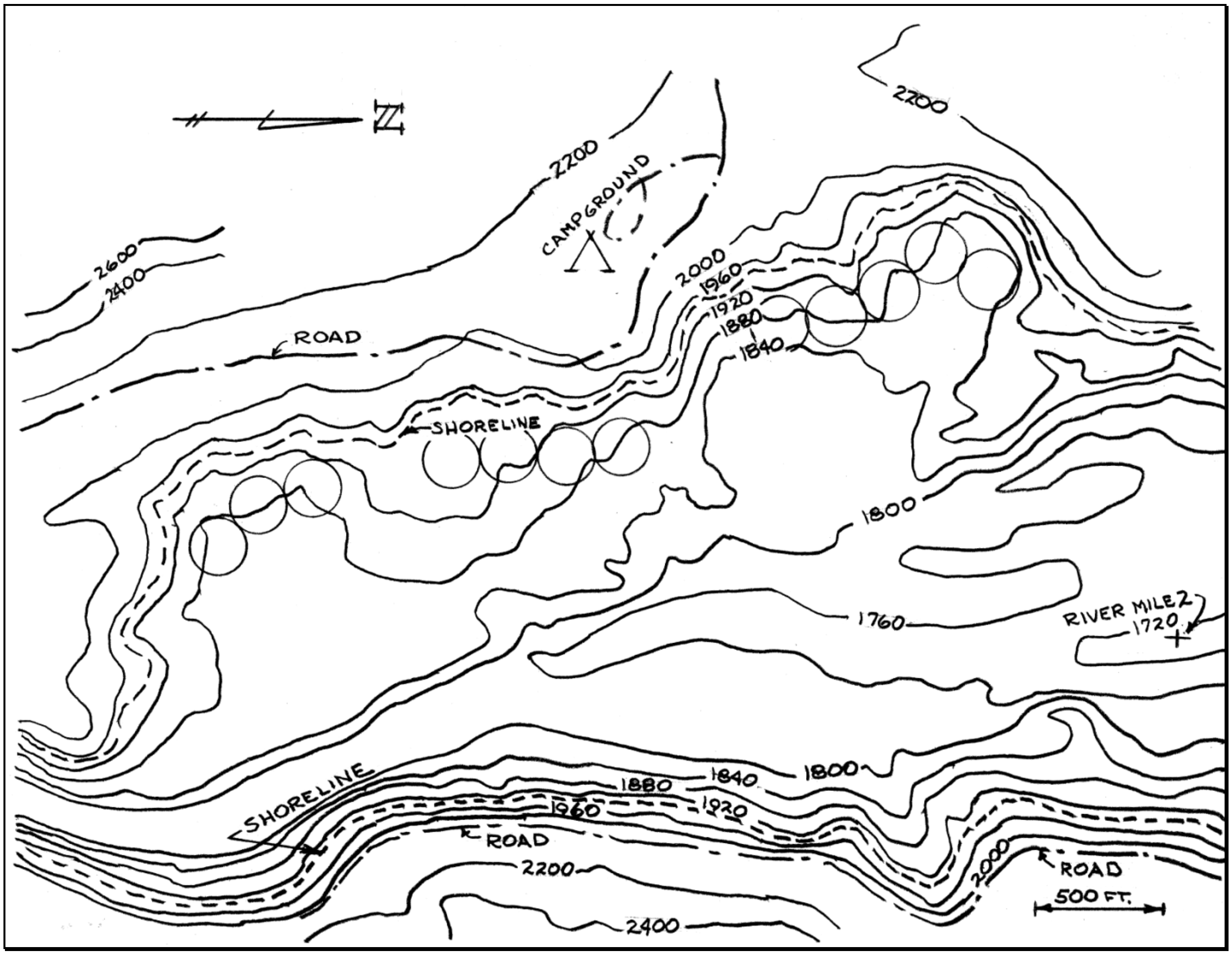
Along the Deschutes Arm, only one site is identified, but it is a good one. It is in a large cove within the Cove Palisades State Park, near to a popular day use area with swimming beach, docks for small-boat tie-up, parking lot and nearby campground. It is adjacent to the peninsula mesa known as "The Island". There is a large area available with gently sloping bottom, which would make an ideal location for houseboat buoys from an engineering point of view. The water depth is only about 60 feet. Seven are feasible.

CR RM 0.4 E



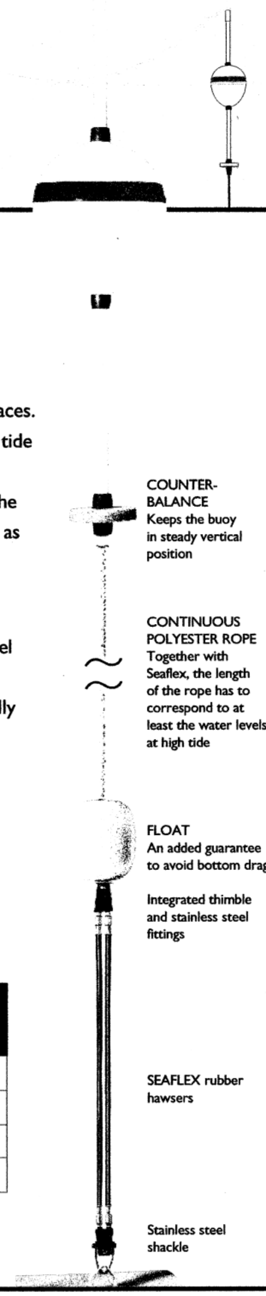
On the Crooked River Arm, there are small coves approximately one-half mile north of the Cove Palisades State Park marina and cabin rentals. The protected areas are not large, but lake depths and bottom conditions make this site suitable for houseboat moorings in this desirable location near juncture of all three arms of the lake. Seven mooring buoys are feasible here.

CR RM 2.2 W



This site is near the end of the wide part of the Crooked River arm. A bridge just upstream restricts motorboat use, which makes this a quiet large cove with much water space. Roads on both sides of the Crooked River arm may limit this site from a scenic and privacy view, but engineering feasibility is good here for twelve or more houseboat mooring buoys.

BUOY



The Seaflex buoy tackles every strain

The Seaflex buoy is a ready-for-use mooring device that provides safe mooring in limited marina spaces. A boat moored to a Seaflex buoy demands less security distance and stays in position regardless of tide and wave movements.

The Seaflex hawser is made of a homogeneous rubber core, armed with a specially braided cord. The unique construction gives a progressive resistance that dampens motion from the water and works as a secure shock absorber even in the harshest weather conditions.

FORGET ANNUAL INSPECTIONS

The rubber hawsers will never be subject to damaging UV rays. Fittings and shackles in stainless steel fight corrosion and deterioration and an age resistant polyester rope has the capacity to handle immense amounts of strain and stress. A Seaflex buoy demands minimal maintenance and successfully reduces the need for inspection.

Light in handling - Seaflex mooring buoy is easily handled by one person

THE ENVIRONMENTAL MOORING

Seaflex is 100% environmentally safe and avoids disturbing sensitive sea bed vegetation. The great flexibility of Seaflex is extended even further through its capacity to adapt to extensive water fluctuations.

BOAT LENGTH	SEAFLEX	ROPE Ø	ANCHOR EYELET Ø	BOTTOM ANCHOR weight
20 ft	1 020	3/4 in	5/8 in	2200 lbs
27 ft	2 020	3/4 in	5/8 in	4400 lbs
33 ft	3 020	1 in	3/4 in	6600 lbs
47 ft	4 020	1 in	3/4 in	8800 lbs

Seaflex®

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SEAFLEX MANUFACTURER'S TECHNICAL INFORMATION

Typical Terrain – Good Mooring Site

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Typical Terrain – More Difficult Mooring Site