FWP PROJECT #
33815A

Upper Red Rock Lake, MT:
Preliminary Engineering and Feasibility Analysis to Improve Winter Habitat for Arctic Grayling

June 22, 2019

CDM Smith

A Report Prepared For:

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Helena, MT 59620-0701
(in cooperation with the U.S. Fish and Wildlife Service)

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Executive Summary

This preliminary engineering feasibility study has been prepared by CDM Smith, Inc. of Helena, MT, with assistance from Confluence Consulting, Inc., to support the Montana Department of Fish, Wildlife & Parks and U.S. Fish and Wildlife Service in evaluating alternatives to improve Arctic grayling (*Thymallus arcticus montanus*) winter habitat in Upper Red Rock Lake (URRL), part of Red Rock Lakes National Wildlife Refuge, Montana.

Low oxygen conditions have been observed during winter months in URRL over the last 20 years and may pose a risk to the genetically distinct grayling population in the lake. Moreover, a relationship between the extent of minimum area of suitable grayling winter habitat and the overall grayling spawning population in the Centennial Valley has been established such that improving winter habitat in URRL is now a management priority.

Accordingly, this conceptual design report has been prepared to identify alternatives that may improve under-ice winter conditions of the lake, in particular dissolved oxygen concentration, thereby potentially ensuring continued persistence of grayling in the Centennial Valley.

The goal of this project is to develop conceptual alternatives that improve or expand winter Arctic grayling habitat such that greater than 4 mg/L dissolved oxygen is maintained at depths greater than 1 meter (3.28 ft) over 25 hectares (62 acres) of the lake during the winter months. The target above has been identified previously by the Centennial Valley Arctic Grayling Adaptive Management Program.

To meet the goal, over 20 alternatives were identified and prioritized that enhance oxygen exchange, add oxygen, or modify bathymetry or circulation. Three alternatives were then selected for conceptual development that are believed to be potentially feasible for lake-wide implementation. Final recommended alternatives include the following:

- Alternative 1 – Mechanical aeration with solar aerators. This alternative proposes to use solar aerators, first in a rental and pilot-level program, and then in full-scale operation (pending outcomes) to oxygenate the deeper water at the center of URRL. Electrical and wind power aeration were also considered, of which electrical is feasible, but may be more difficult to implement from a permitting and minimum requirements analysis standpoint due to the wilderness designation of URRL.

- Alternative 2 – Tributary diversion and point of inflow modification. This alternative diverts existing water from one or more tributary inflows and moves the point of entry from shallow shoreline areas that currently do not meet the established depth criterion to the center of the lake which does. A gravity pipeline alignment and in-lake diffusers are proposed that leverage existing topography and tributary storage features (e.g., Shambow or Widgeon pond). It is believed this alternative may more difficult to permit since it permanently modifies the wilderness character of URRL.

- Alternative 3 – Dredging or lake modifications. This alternative would increase depth near the tributary mouths such that these locations meet both the oxygen and depth criterion, leveraging incoming water that is already at atmospheric saturation conditions. Over 300,000 cubic yards of excavation would be required for this alternative to achieve the 25 hectares of required habitat. Due to the considerable cost in dredging and material handling, this the most expensive of all options. More importantly, dredging may be very difficult to implement from a minimum requirements analysis due to the large levels of disturbance during construction.

Of the three alternatives identified above, Alternative 1 is preferred for URRL since it is believed to have least impact to the wilderness designation of the site and has the best chance of success. Alternative 2 is also very attractive in that it is easy to construct but may be difficult to implement from a wilderness perspective. Alternative 3 is the least favorable since it is very expensive and causes considerable site disturbance. A "no action" alternative was not included as part of the evaluation since it will not attain the stated dissolved oxygen concentration and depth to support grayling in URRL.

Finally, a pilot study and monitoring program is recommended that will include the rental and installation of a solar-powered aerator during the winter of 2019-2020 (i.e., Alternative 1) that will both improve lake conditions and allow performance monitoring of the implementation. Dissolved oxygen, turbidity, and temperature responses should all be monitored in real-time. Other data collection activities are also recommended to support Alternative 2 and Alternative 3 along with a discussion of likely permitting requirements for each alternative.

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Section 1

Introduction

This preliminary engineering feasibility study has been prepared by CDM Smith of Helena, MT, with assistance from Confluence Consulting Inc. (Confluence), to support the Montana Department of Fish, Wildlife & Parks (FWP) and U.S. Fish and Wildlife Service (USFWS) in evaluating alternatives to improve Arctic grayling (*Thymallus arcticus montanus*; hereafter referred to as grayling) winter habitat in Upper Red Rock Lake (URRL).

Low oxygen (hypoxic, < 2 mg/L dissolved oxygen) conditions have been observed in URRL during winter months by several investigators over the last 20 years and pose a risk to the genetically distinct grayling population in the lake (Davis, 2016; Davis, McMahon, Cutting, & Jaeger, unpublished; Gangloff, 1996; Warren, et al., 2018). Moreover, a relationship between the extent of minimum area of suitable grayling winter habitat and the grayling spawning population in the Centennial Valley exists (Warren, et al., 2018) such that improving winter conditions in URRL has become a priority. Accordingly, this preliminary engineering design report has been prepared to identify and analyze alternatives that can improve under-ice winter conditions in the lake, thereby potentially supporting the continued persistence of grayling in the Centennial Valley.

The conceptual design report has been structured as follows to address critical winter habitat conditions in URRL: (1) by reviewing alternatives and available technologies that enhance oxygen exchange or increase depth to reduce oxygen depletion during ice covered conditions, (2) screening of those alternatives for applicability to URRL, (3) literature review and development of engineering models and empirical tools to complete predictive evaluation of dissolved oxygen (DO) concentrations in the lake after alternative implementation, (4) preparation of conceptual design alternatives that improve future conditions, and (5) consideration of pilot study recommendations supporting alternative implementation.

1.1 Purpose and Authorization

Authorization for this work is provided by FWP under Architect or Engineering Design Services Project # 33815A. Initial concepts have been developed in coordination with FWP, USFWS, and other relevant agency staff/programs including the U.S. Forest Service, Bureau of Land Management, and Montana State University (i.e., organizations that are collectively working on grayling conservation in the Centennial Valley). The conceptual design report is but a small piece of the much larger Centennial Valley Arctic Grayling Adaptive Management Project (Warren & Jaeger, Centennial Valley Arctice Grayling Adaptive Management Plan, 2017).

1.2 Scope of Project and Report Organization

The scope of the project includes the following activities that were completed in support of the conceptual design to improve conditions in URRL by increasing the number of hectares of suitable grayling habitat, organized by section of the report:

- **Section 2 – Preliminary Alternative Identification:** reviews relevant literature and identifies preliminary alternatives for URRL based on stakeholder knowledge of the lake. It also details screening criteria used in alternative selection, including preliminary consultation with relevant permitting agencies to inform alternative selection;
- **Section 3 – Model Development:** discusses evaluation of existing data including the development of zero-dimensional (0-D) and 2-D dissolved oxygen models to quantify winter oxygen depletion rates and dissolved oxygen responses of proposed engineering alternatives targeted at achieving the winter habitat goals in the lake;
- **Sections 4 through 6 – Alternative Analyses:** details conceptual design alternatives including aeration, modification of circulation, and dredging of URRL, and permitting and policy considerations for implementation. Each alternative was developed to a conceptual level of design of 2%, with an opinion of probable construction cost (OPCC) at a level of accuracy commensurate with an AACE Class 5 estimate level (AACE, 2005);
- **Section 7 – Pilot Study Recommendations:** discusses a phased implementation program aimed at experimental pilot-testing of certain technologies to verify feasibility and effectiveness prior to full scale lake-wide implementation, while at the same time collecting data to fill gaps for several of the alternatives.
- **Section 8 – Conclusion:** reviews findings for improving winter grayling habitat in URRL with respect to engineering and regulatory requirements, including consideration of requirements for work in a designated wilderness.

The goal of the project is to develop conceptual engineering alternatives that create or expand habitat in Upper Lake to achieve > 4 mg/L dissolved oxygen and depth >1 m over 25 hectares (62 acres) in URRL lake during winter conditions.

1.3 Site Background

1.3.1 Study Area and Problem Statement

URRL is located in southwestern Montana approximately 43 miles southeast of Lima (latitude 44.60990° and longitude −111.72172°) in Beaverhead County, part of the Red Rock Lakes National Wildlife Refuge (RRLNWR; Figure 1-1). The site is remote and can be accessed by car from L-1-205N (Lima Dam Road) via Lima, MT or Route 509 from Monida, ID from the west, or by L-1-201N (South Valley Road) out of Henrys Lake, ID from the east. Lake access is directly available from South Valley Road by way of a non-wilderness campground on the southwestern side of the lake. The nearest town is Lakeview, MT which is approximately four miles to the west. URRL, along with it companion wetland complex of Swan Lake and Lower Red Rock Lake are part of approximately 51,000 acres of open water, marsh, dry sagebrush uplands, fertile hay meadows, and forested regions of the rugged Centennial mountains (Paullin, 1973). URRL and its tributaries drain to the Red Rock River, and the entire project site is within the RRLNWR managed by the USFWS.

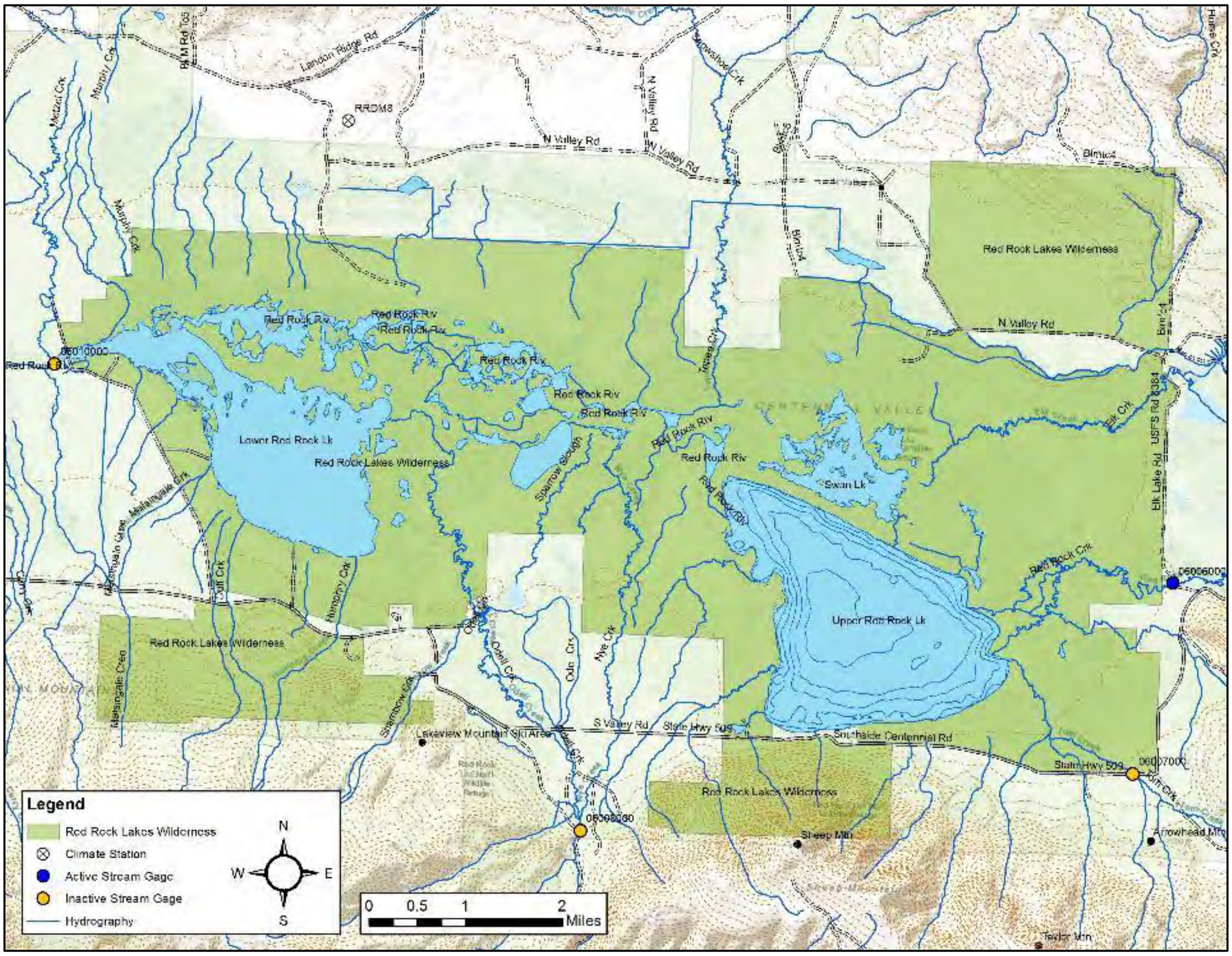


Figure 1-1
URRL site map

1.3.2 Climate

URRL is located at an elevation of 6,600 feet in the Centennial Valley, bordered by the low rolling Gravelly Range to the north and the rugged Centennial Mountains to the south. Climate is characteristic of long cold winters and short cool summers (Paullin, 1973). Pacific storms track across the Snake River Plain from southern Idaho into the Centennial Valley during winter and spring resulting in a precipitation gradient from west to east along the mountain front[1]. In summer, the valley is influenced by a persistent northeastern subtropical high-pressure zone that suppresses precipitation across the region (Mumma, Whitlock, & Pierce, 2012) and leads to periods of clear weather (MesoWest, 2019).

Climatic drivers are apparent in examination of monthly precipitation and temperature normals (Figure 1-2). Annual precipitation in the URRL region averages just under 20 inches, with May and June being the wettest months and the driest months being July and August. Monthly maximum air temperatures approach the mid-70s or low-80s (°F) during the summer while

[1] This is illustrated by the White Elephant (7,710 ft a.m.s.l.) and Lakeview Ridge (7,400 ft a.m.s.l.) Snow Telemetry (SNOTEL) sites in the eastern and central portion of the Centennial Mountains, respectively. White Elephant has approximately double the average the snow water equivalent at the end of winter than does Lakeview Ridge.

winter has monthly lows that approach 0°F. Temperature inversions in the Centennial Valley are common during the winter months, sometimes lasting for days. It is common to see a 50°F difference in air temperature between the town of Lakeview, MT and the Lakeview Ridge SNOTEL site one mile to the south and approximately 700 feet higher in elevation.

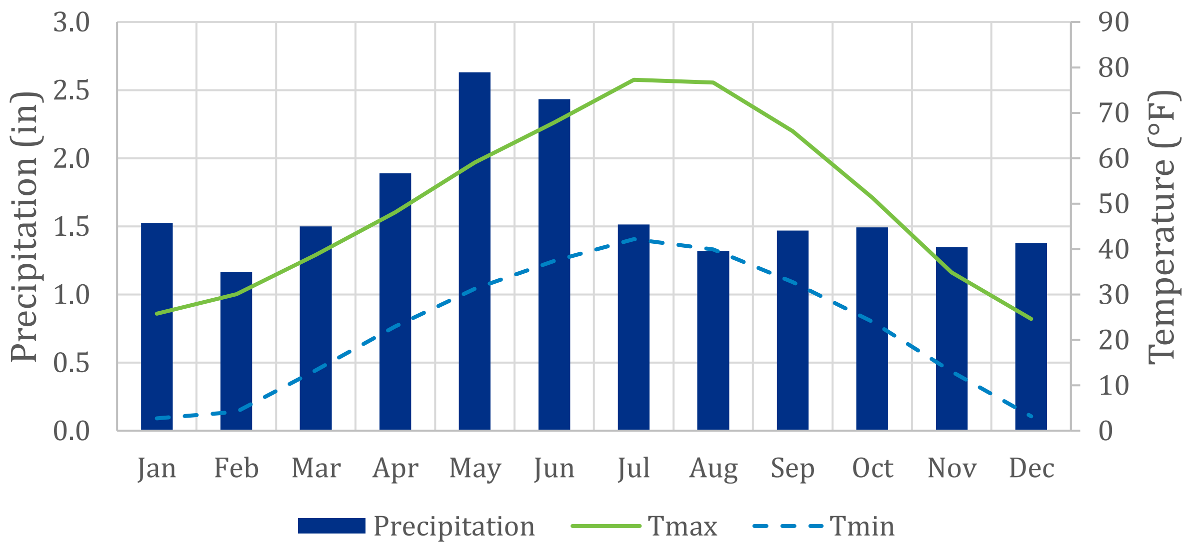


Figure 1-2
Temperature and precipitation normals (1981-2010) at URRL (gridMET, 2019)

1.3.3 Hydrology

URRL is fed by five streams including Red Rock Creek, Elk Springs Creek, Grayling Creek, Shambow Creek, and Tom Creek. Of these, Red Rock Creek contributes the largest volume of surface runoff (Gangloff 1996) and is the only site that is currently gaged by the U.S. Geological Survey (USGS). Tom Creek has also been gaged historically by USGS and is currently monitored seasonally by FWP (2016-2018). Flows exit the lake through a single outlet located in the northwest corner of the lake that connects URRL to the much shallower Lower Red Rock Lake and Red Rock River. Drainage area and winter streamflow approximations for tributaries to URRL are summarized in Table 1-1. Only winter flows are characterized since they are most relevant to oxygen deficiency in URRL.

Table 1-1 USGS streamflow gages contributing to URRL

Gage ID	Description	Drainage Area (mi^2)	Estimated Average Winter Flow (ft^3/s) [a]	Period of Record
06006000	Red Rock Cr ab Lakes nr Lakeview MT	37.3	20.2	1997-current
06007000	Tom Creek near Lakeview MT	6.95	0.5 (1.5 FWP)	1989
ESC	Elk Springs Creek	37.1[b]	9.8	2016-2018
SC	Shambow Creek	0.3 [b]	0.1 [c]	Regression
GC	Grayling Creek	2.3 [b]	0.9 [c]	Regression

[a] Taken as the average of the first and last observations for seasonal gaging records.
[b] Drainage area computed using USGS 1/3 arcsecond National Elevation Dataset (NED) in ArcGIS.
[c] Flow estimated through regression.

The typical streamflow hydrograph for Red Rock Creek (USGS gage ID 06006000) is shown in Figure 1-3. Streamflow is characteristic of a snowmelt-dominated system with the rising limb of the hydrograph beginning in early April, peak flow in June or July, and recession to baseflow during fall and early winter. Daily flows range from just over 10 to nearly 300 ft^3/s during the seasonally gaged period. Winter flow cannot be directly ascertained, but can be inferred from spring and fall observations. On a percentile basis (e.g., 5th and 95th percentile), winter flows will range from between 10 to 40 ft^3/s, with an estimated median of approximately 20 ft^3/s.

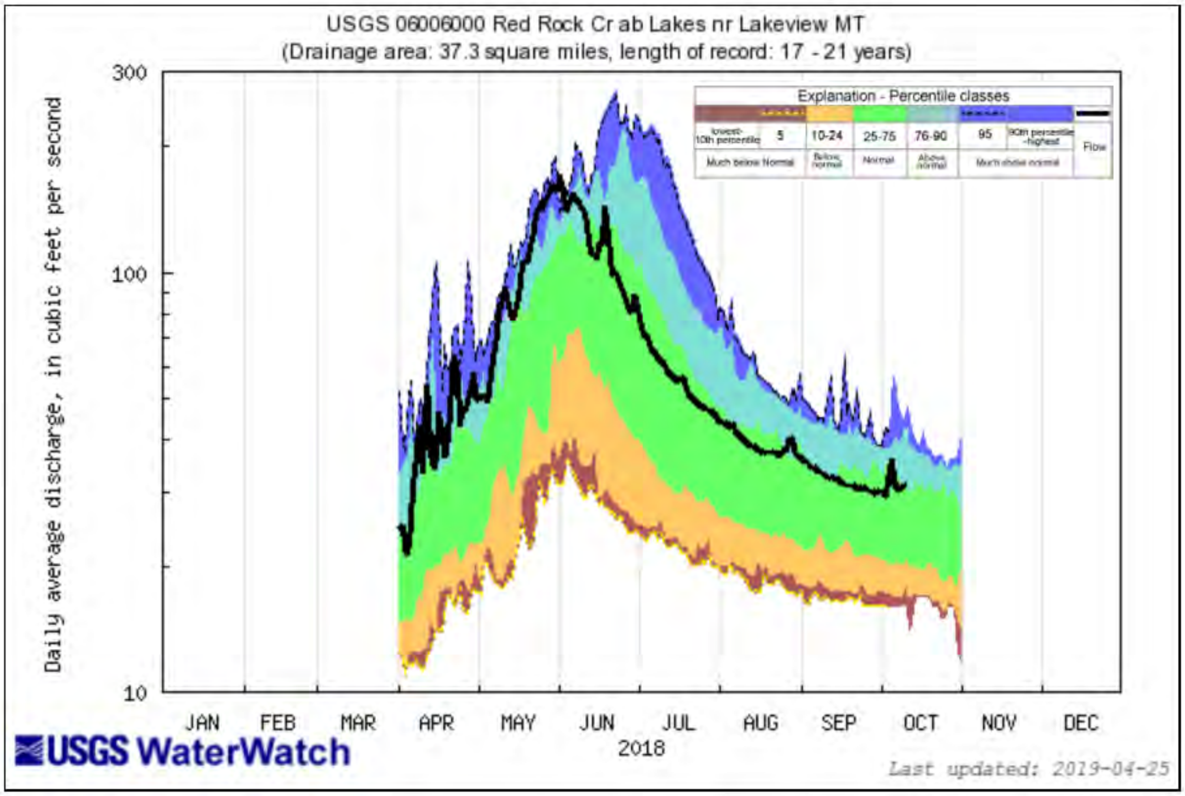


Figure 1-3
Streamflow for USGS 06006000 Red Rock Creek above lakes near Lakeview, MT
The most recent hydrograph from the 2018 calendar year is shown (black line).

Other tributaries to the lake presumably have a similar hydrologic response to that shown in Figure 1-3 and should approximately scale in proportion to contributing drainage area. To fill data gaps, flows for ungaged tributaries (Shambow and Grayling Creeks) were estimated using the drainage area regression shown in Figure 1-4. We recommend that data be collected at these locations in subsequent winters (in addition to other incoming tributaries) to better understand the hydrologic balance of URRL prior to implementing activities discussed later in this document.

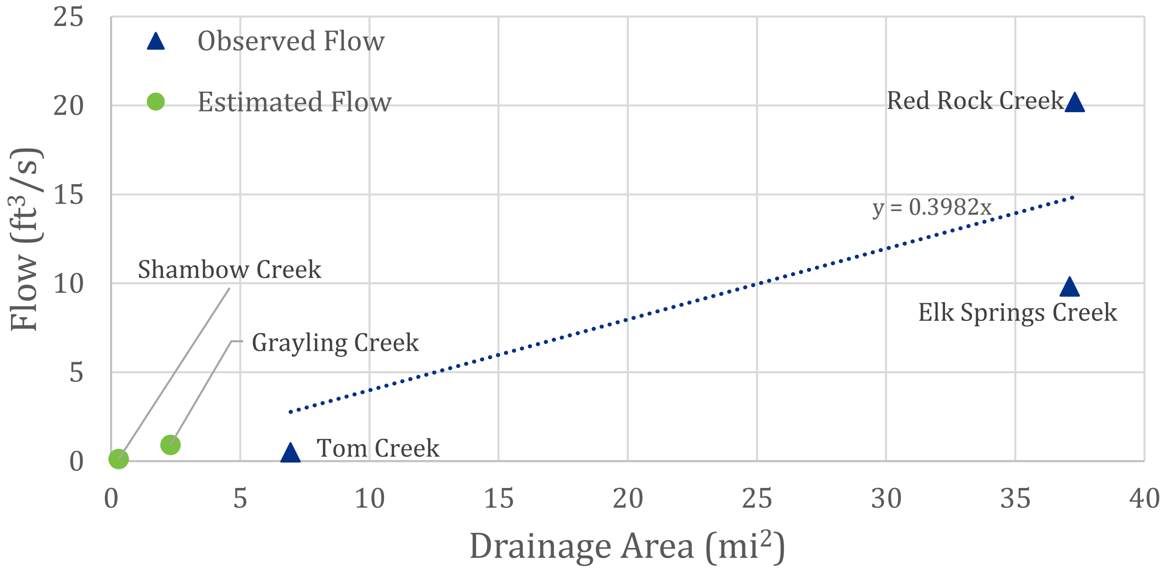


Figure 1-4
Drainage area regression used to estimate streamflow during winter months

1.3.4 Limnology and Bathymetry

URRL is a high-elevation, shallow postglacial wetland depression remnant of the historical Pleistocene Lake Centennial that once covered the eastern Centennial Valley (Mumma, Whitlock, & Pierce, 2012). With a surface area of approximately 893 hectares (2,207 acres), maximum depth of 2 m (6.56 ft) (Gangloff, 1996), and volume of 0.0128 km^3 (10,342.9 acre-feet) (Montana Fish Wildlife and Parks, 2012), the lake is approximately 6 km (3.73 mi) long and 3.5 km (2.17 mi) wide. Due to shallow depths, prolonged snow cover, and enriched organic sediments, winter hypoxia (DO < 2 mg/L) is common. Like many high-altitude lakes in northern latitudes, freeze-over typically occurs in November and remains ice-covered until early May (Gangloff, 1996). Presumably the lake is polymictic (i.e., too shallow to stratify) in the summer months and is fully aerated at the time of ice cover. Based on the winter inflows noted previously (31.5 ft^3/s; Table 1-1), the winter hydraulic residence time[2] is estimated to be 165 days, explaining why inflows do not fully oxygenate the lake during winter. The high sediment surface area to lake volume ratio (0.93) further contributes to oxygen deficiency (Mathias & Barica, 1980), as shallow depths, abundant rooted macrophytes, and benthic substrate of mud, peat, and detritus (Davis, 2016) give it many characteristics typical of eutrophic winterkill-prone lakes.

1.3.5 Land Ownership

URRL is part of the RRLNWR, which is one of the few designated wetland wilderness areas in the country. The refuge was established in 1935 to protect breeding grounds for trumpeter swans (Paullin, 1973) and comprises 51,435 acres of land managed by the USFWS, along with conservation easements totaling an additional 23,805 acres and 9,600 acres of state leased land. The designated wilderness boundary is shown in Figure 1-1. It is important to point out that a

[2] Hydraulic residence time (HRT) is the average time a volume of water stays within the lake and is calculated as follows: HRT = V/Q, where V = volume (m^3) and Q is flow (m^3/s).

small sliver of South Valley Road right-of-way runs through the RRLNWR designated wilderness, which connects to the campground on the south side of the lake. An original plat map supporting this determination is in Appendix A. The non-wilderness access road and shoreline area along the campground allow direct lake access for mitigation options discussed later in the document.

1.4 Problem Statement

Arctic grayling are a rare endemic species found only in the Upper Missouri River Basin of the contiguous United States and have drawn recent attention for potential listing under the Endangered Species Act. URRL is believed to contain one of the few viable native adfluvial (lake-dwelling) populations of grayling south of Canada and Alaska (Gangloff, 1996) and it is suspected that much of the Centennial Valley grayling population migrates into and occupies URRL for the winter, making it critically important to the continued existence of the species. Yet it is possible that some grayling survive the harsh overwinter conditions of URRL by residing in the streams during most of the year. The population is believed to have genetic differences from populations elsewhere and has undergone significant declines in abundance and distribution in recent years (Davis, 2016).

Winter monitoring indicates that the under-ice habitat quality in URRL is poor some years due to extended snow and ice cover, macrophyte abundance, and sediment oxygen demand (SOD). As such, oxygen deficiency is at least one factor attributed to the recent grayling population decline. Between 2015 and 2016, the spawning population of grayling experienced a four-fold decline, from 1,100 to less than 300 individuals (Warren J. , et al., 2018). In response to this drop, managing agencies have identified the need to improve winter habitat in URRL. Based on an examination of empirical data, at least 25 ha with >4 mg/L of dissolved oxygen and depth >1 m has been proposed as an interim management target. Using these criteria, less than 2% of the 893 ha (47 acres) of URRL has been suitable for grayling over the past three winters.

1.5 Previous Studies and Investigations

Prior studies of oxygen deficiency in URRL are summarized below with respect to winter habitat. Please note that the list is not exhaustive but is believed to include the primary body of literature on the topic.

- Gangloff (1996) investigated the chemical and physical limnology of URRL during the winters of 1994 to 1996 as part of a master's thesis funded by USFWS to understand winter impacts to Arctic grayling. The lake exhibited different responses each year, but the winter of 1994–1995 was noted as being nearly deficient of DO (hypoxic; <2 mg/L). Radio-tagged grayling congregated in two primary areas of refugia around the mouths of tributaries that year (Red Rock Creek and Grayling Creek), but not when lake DO was higher, suggesting impingement of habitat. Oxygen deficiencies were believed to be related to snow and ice cover along with a large macrophyte biomass that had developed during the preceding summer and fall months.

- Davis (2016) authored a master's thesis with support from FWP and USFWS utilizing data collected in the winters of 2013 to 2015 to assess low dissolved oxygen (DO) levels in the lake, particularly during the winter of 2013–2014. The study found that while low oxygen conditions prevailed one winter, the lake still had DO >4 mg/L at the ice-water interface. Davis concluded low winter survival was perhaps not a limiting factor for grayling, as adequate oxygen existed near the ice-water interface. A follow-up study, in draft manuscript, reports similar findings. To our knowledge, that paper has not been published.

- Routine winter monitoring also has been completed by USFWS during 2011, 2016, 2017, and 2018. These data have contributed towards the Centennial Valley Arctic Grayling Adaptive Management Project completed by FWP and USFWS. Results are discussed in annual reports describing annual fish surveys, modeling, and winter oxygen monitoring. Notably, there appears to be a quantifiable relationship between winter oxygen deficiency and fish population. In the most recent report (Warren, et al., 2018), all years with less than 25 ha (62 acres) of suitable winter habitat in URRL correlate to a depressed grayling population the following year. Experimental treatments such as reducing interspecific competition among fish species and improving spawning habitat have been attempted but were largely unsuccessful.

The studies above provide a fundamental basis for our effort by demonstrating that oxygen deficiencies frequently occur in URRL, establish a link between grayling population and winter habitat, and indicate the potential risk for winterkill is real based on the lake's physical features and available monitoring data. It is important to note that telemetry data to date (Gangloff 1996 and Davis 2016) have not documented large overwinter fish kills. Rather, this claim is supported through annual monitoring of overwinter lake conditions and the number of spawning grayling the subsequent spring in Red Rock Creek.

Finally, the intent of this document is not to provide an exhaustive review of shallow lake hypoxia or mechanisms of winterkill in shallow ice-covered lakes. A suitable review of this topic can be found in Davis (2016), Ganglofff (1996), and Davis et al. (unpublished), all of which are directly relevant to URRL. Widely-cited literature also exists on factors controlling oxygen depletion in ice-covered lakes, winterkill, and winter deoxygenation phenomena (Kirillin, et al., 2012; Barica, Gibson, & Howard, 1983; Fast, 1994).

1.6 Goals and Objectives

The goal of this project is to improve winter habitat for Arctic grayling in URRL by identifying alternatives that can achieve the Centennial Valley Arctic Grayling Adaptive Management Project (AMP) objective of > 4 mg/L dissolved oxygen in areas of the lake with a depth >1 m for at least 25 ha of the lake during winter conditions. Specific tasks to achieving the goal include identifying available technologies or alternatives, screening those based on benefit, estimating costs, determining reliability, and then developing three conceptual alternatives that can be applied to URRL and implemented in pilot-level testing. All potential engineering options, treatments, or technologies that can be used to improve winter habitat conditions within URRL in a reliable and cost-effective manner have been considered.

Section 2

Alternative Identification and Selection

This section describes the alternative identification and screening procedures used in selecting the three conceptual alternatives to improve overwinter grayling habitat in URRL.

2.1 Alternative Identification

Initial alternatives were identified as part of a stakeholder meeting held on February 20, 2019 and were later supplemented with information from CDM Smith and Confluence based on literature reviews and vendor-supplied information. All conceivable actions that might improve overwinter conditions in URRL were initially considered. Decision theory was then used to rank and screen the list down to three final alternatives.

Initial alternatives identified for improving winter conditions in URRL are shown in Table 2-1. Alternatives were grouped into four types: (1) mechanical aeration, (2) physical treatments, (3) bathymetric modification, or (4) circulation enhancement. Three of these initial alternatives were selected and carried forward into conceptual design.

Table 2-1 Potential alternatives to improve overwinter conditions in URRL

Type	Option/Alternative
Mechanical Aeration	Diesel/propane, Electrical, Wind, Solar
	Mechanical mixing
Physical Treatments	Snow removal/carbon application
	Snow fencing
	Vegetation treatments
	Ground source heat
	Molecular O_2 addition
	Ice removal
	Pumping water onto ice
	Fish population manipulation
Bathymetric Modification	Dredging
	Blasting at tributary inlets
	Lake outlet modification
	Lower lake dam operation
	Sediment sill/groins
Circulation Enhancement	Increase inflow (groundwater/surface water)
	Move tributary point of inflow (POI)
	Restructure Elk Springs Creek at POI
	Develop springs/pull boards
	Impound tributaries
	Flood irrigation

2.2 Screening Approach

The screening approach for each alternative was developed from stakeholder input and consisted of a multi-objective weighted decision matrix that scored environmental benefit and constructability along with other factors. The objectives, weighting categories, and scoring criteria used in screening are given in Table 2-2. A broad range of criteria were included that addressed cost, visual and auditory aesthetics, operation and maintenance, reliability, policy or permitting limitations, habitat connectivity, and other guiding factors.

Environmental benefit and constructability were considered essential binary outcomes because both are critical to the success of the alternatives. They therefore have primacy over all other scoring criteria. For example, if an alternative would not result in the minimum winter habitat target of 25 ha of habitat with >4 mg/L DO in >1 m water, it was removed from further consideration. Likewise, if a project alternative could not be implemented from an engineering or regulatory perspective, it was also eliminated. Scoring ranges were structured in such a way that if an alternative positively influenced, or was beneficial to the objective, it would score near the top of the range. If it negatively influenced the project objective, it would score near the bottom of the range (see table footer).

Table 2-2 URRL decision matrix objectives, weightings, and scoring criteria

Objective	Weighting	Score [a]	Max Score	Description
Environmental Benefit	25	0, 1	25	Capacity of project to achieve 25 ha of minimum winter habitat (> 1 m deep and > 4 mg/L DO)?
Constructability	25	0, 1	25	Can the proposed project be implemented?
Cost	1	1–5	05	Relative cost of the proposed project?
Aesthetic/Footprint	4	1–5	20	What are the viewshed, noise, or disturbance areas associated with project?
Operation and Maintenance (O & M) Frequency/Duration	3	1–5	15	How often, and how much O & M is required?
Reliability	4	1–5	20	Will the project reliably or consistently meet the environmental objective?
Policy/Permitting	3	1–5	15	Can the project be implemented under existing policy and permitting constraints?
Connectivity	3	1–5	15	Can habitat connectivity in URRL be established with the project (i.e., based on DO)?
Immediacy	3	1–5	15	Will there be immediate benefit from the project or is the benefit longer term?
Tangential Benefit(s)	3	1–5	15	Are there any other possible benefits besides improving DO concentration in URRL?
Risk/Uncertainty	3	1–5	15	Are potential adverse impacts or other uncertainties foreseen?

[a] Scoring was implemented as follows for each objective: cost (low = 5, high = 1); aesthetic/footprint impact (low=5, high=1); O&M (low=5, high=1); reliability (low=1, 5=high); policy/permitting (low=5, high=1); connectivity (low=1, high=5); immediacy (soon=5, long term=1); tangential benefits (1=none, 5=many); risk/uncertainty (low=5, high=1).

To implement the screening process, each alternative was given a respective fixed weight by the stakeholder group based on relative priority, along with a relative scoring range. Scores were then independently assigned to each objective based on the professional judgment of three senior experts from CDM Smith and Confluence. The following disciplines were consulted: limnological and environmental engineering, engineering design and construction, and policy and permitting. Stakeholder feedback was also solicited separately from FWP and FWS project managers. Results of the decision-matrix are shown in Figure 2-1. Combined scores (including weighting factors), and individual scoring sheets are found in Appendix B.

As is noted in Figure 2-1, several alternatives ranked in the upper 20% or had standard deviations projecting into the upper 20th percentile. As such, these alternatives underwent further consideration as detailed in subsequent sections. High-ranking alternatives included mechanical aeration (various types, discussed later), dredging, lake outlet modification, blasting at tributary inlets, moving the point of entry of existing streams, developing tributaries to improve inflow, and groundwater pumping and mechanical mixing. Components of each of these alternatives are discussed in the context of the selection of the final three alternatives later.

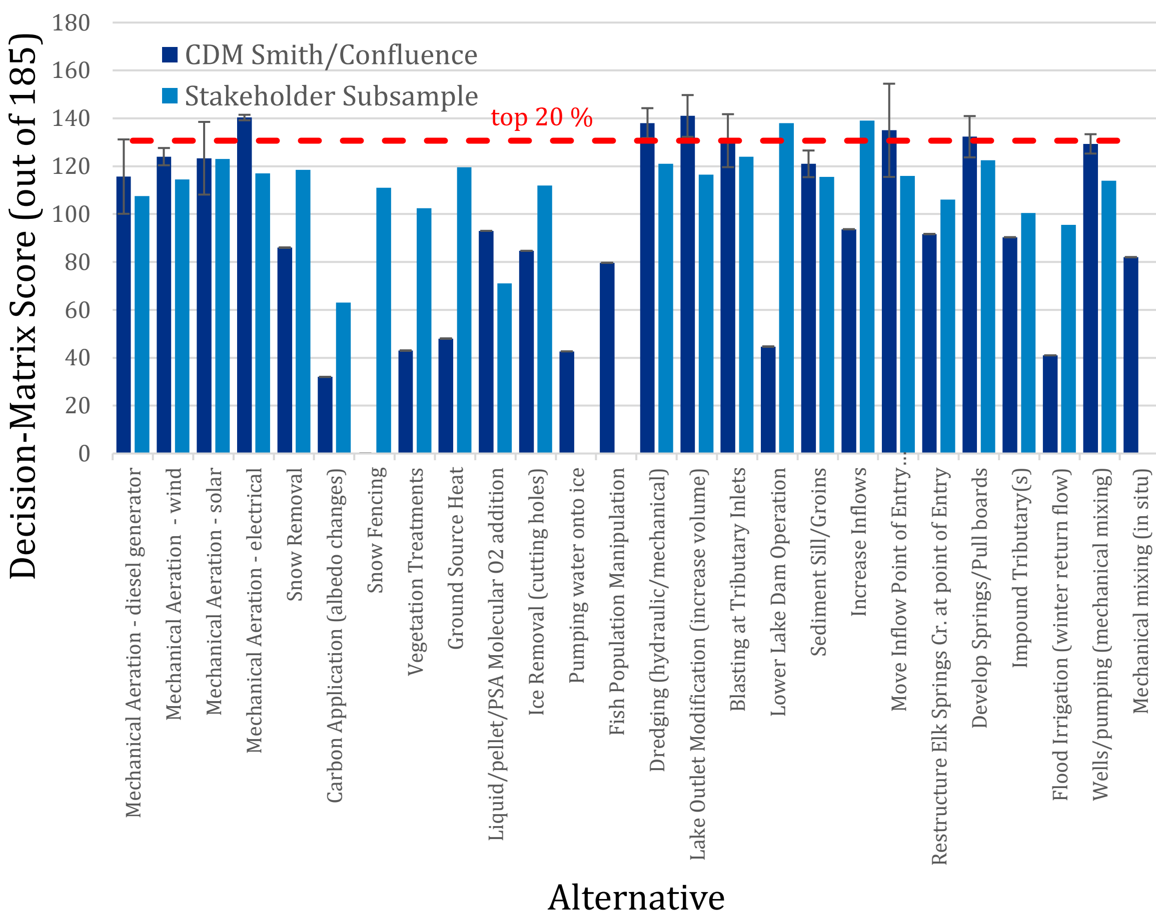


Figure 2-1
Decision-matrix rankings for various alternatives identified in the feasibility study
Rankings based on expert opinions. Standard deviation of the response is noted by the whiskers.

2.3 Alternative Descriptions and Information

Many strategies have been implemented for preventing winterkill or oxygen deficiency in shallow eutrophic lakes (Ellis & Stefan, 1989; Fast, 1994). These are discussed briefly below in the context of the feasibility study.

2.3.1 Mechanical Aeration

Mechanical or artificial aeration has been widely used to prevent lake or pond winterkill (Fast, 1994). Methods typically involve air injection under the ice, aeration of a pumped water stream, surface splashers, or molecular oxygen addition. The underlying principles are the same: enhancing oxygen concentrations through either direct oxygenation or melting ice and therefore creating an area of open water that provides atmospheric gas exchange (hereafter referred to as a "polynya"). Each general concept is shown in Figure 2-2.

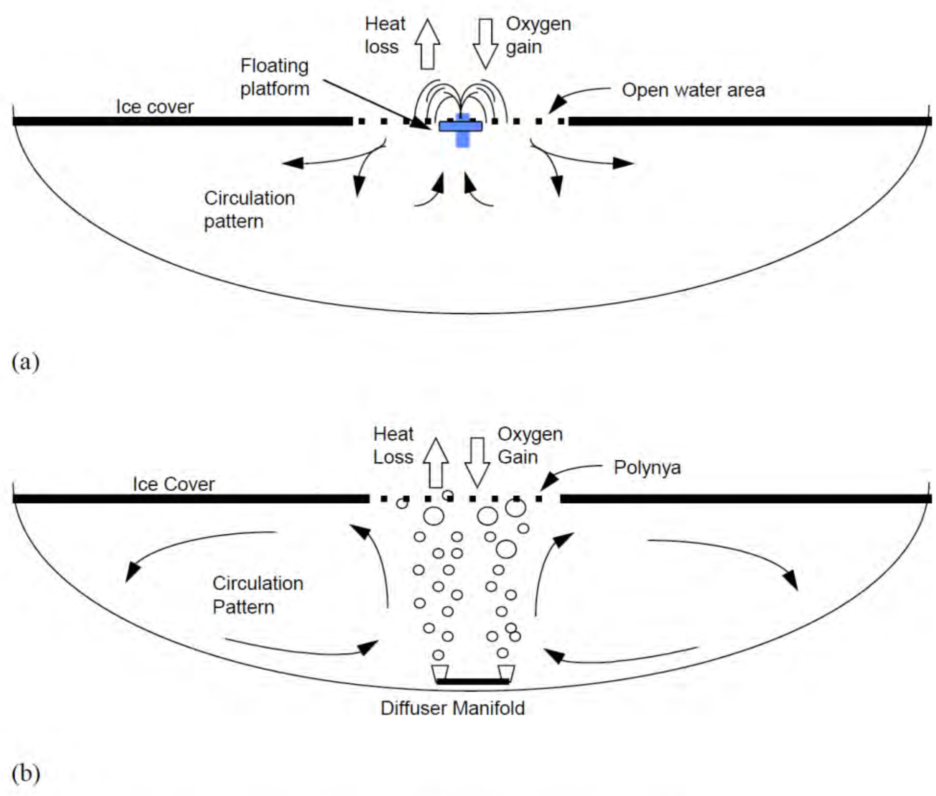


Figure 2-2
Mechanical aeration approaches and circulation in ice-covered lakes
(a) Example of mechanical surface aerator or splasher. (b) A point-source bubbler. Taken from McCord (1999) and McCord et al. (2000).

According to Ashley and Nordin (1999), a primary consideration in the design of aeration systems is whether electric power can be supplied to the site. Remote locations (e.g., URRL) often do not have connections to the electrical grid and therefore aeration options are limited. Ashley (1987) describe several different aeration technologies used in remote locations in British Columbia. The following rankings were ascribed in terms of increasing complexity:

1. Wind powered circulation
2. Solar powered circulation
3. Electric surface aerator
4. Electric blower
5. Electric compressor
6. Diesel/propane blower

Although renewable energy systems are ranked above fossil fuel systems, barriers to the adoption of solar and wind power sources include such problems as intermittent power supply and high capital cost. These issues are less important for lake aeration due to the small elevation head differences used in circulation or destratification (Kirke B. , 2000). However, when renewable sources such as wind or solar are used as the sole source of energy, battery storage must be provided on-site (Kirke B. , 1995). A brief review of each of these aeration types is provided below.

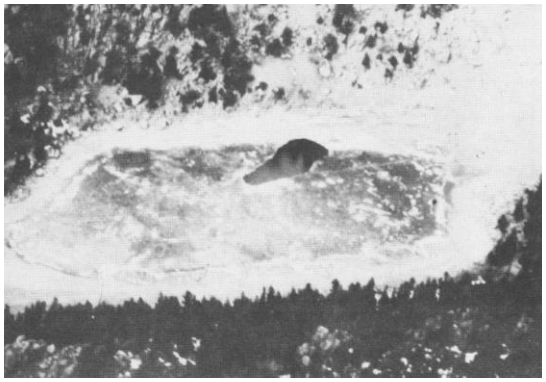
Potential limitations of aeration devices include whole lake cooling (from increased exposure of the water to the atmosphere), resuspension of sediments due to mixing that can increase water column oxygen demand, or increased SOD rates due to disturbance of the diffusion boundary layer at the sediment-water interface. More details on aeration can be found in Section 4 of the Preliminary Engineering and Feasibility Analysis.

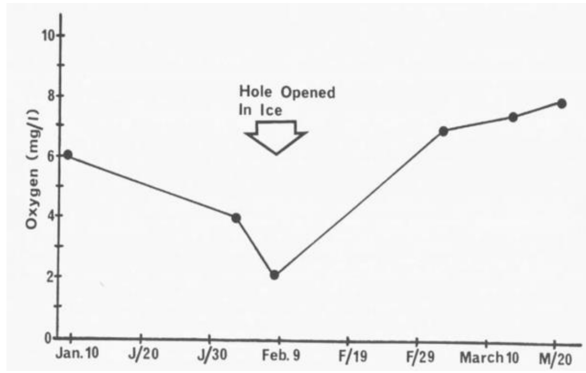
2.3.1.1 Diesel or Propane Aerators

Prior experience with internal combustion-powered equipment (e.g., gasoline, diesel, and propane powered compressors or generators) for aeration in British Columbia suggest they are not appropriate for unattended operation in remote locations (Ashley & Nordin, 1999). Excessive noise, emissions, and re-fueling and maintenance considerations present significant operational challenges. Moreover, diesel or propane aeration systems have been shown to be repeatedly unreliable. Given URRL's remote location, on top of being part of a designated wilderness area, internal combustion aeration equipment has been eliminated from further analysis.

2.3.1.2 Wind Circulators/Aerators

Wind powered circulators convert wind energy into compressed air that is then transported through tubing to an in-lake diffuser (Schierholz, Somervell, Babcock, Hartel, & Timbre, 1975). Applications have been shown to be effective in small lakes (Fast, 1994; Schierholz, Somervell, Babcock, Hartel, & Timbre, 1975); however, rarely have they been applied to systems as large as URRL. A successful wind aeration application is reported on Lost Lake, located near Red Feather Lakes Colorado, by Schierholz et al. (1975), noting the windmill aerator opened a sizeable ice-free area in the lake (Figure 2-3a). It also greatly improved oxygen concentrations at the onset of operation (Figure 2-3b). Lost Lake is much smaller than URRL (2.5 ha vs. 863 ha) and has several advantages with respect to lake size and wind speed. Other wind power aeration studies have been unsuccessful due to inconsistent winds and mechanical breakdowns of wind-powered compressors (Fast, 1994)[4].





(a) **(b)**

Figure 2-3
Aerial photograph of Lost Lake, Colorado during operation of a wind aeration system
(a) Aerial photograph of polynya opening. (b) Associated dissolved oxygen response. (reproduced from Fast 1994).

2.3.1.2 Electric Aerators

Electric aerators are one of the most widely used technologies for preventing winterkill in lakes (Fast, 1994) and have received attention from many authors (McCord, Schladow, & Miller, 2000; Miller & Mackay, 2003; McCord & Schladow, 2001). Electric aerators can generally be grouped into two types: splashers or surface aerators (typically observed in wastewater treatment applications) and compressed air bubblers. The difference between each is the relative depths at which water is withdrawn or displaced. The bubbler's diffuser manifold is typically located just above the sediment in deep water, drawing water from all depths toward the surface, while the splasher floats on the water surface and draws water into a shallow intake. Aeration is primarily attributable to surface turbulence in the polynya and is augmented by some gas transfer from the rising air bubbles[5].

2.3.1.3 Solar Mixers

Solar-powered aeration is another potential renewable technology that was considered for URRL. It has been used for reservoir mixing or destratification and aeration of wastewater treatment plant facilities (EPA, 2005), but less extensively for winter aeration. Solar panels, also known as photovoltaic (PV) cells, convert sunlight directly into electricity and have been mounted on top of floating surface aerators so the system components are exclusive to the aeration location, meaning no wires or pneumatic lines are required. A back-up battery power source is often required. Solar aerators require only sunlight as fuel, which is a renewable energy source, have

[4] The authors own personal experience in wind aeration of small-scale ponds indicates such methods will be difficult to scale to URRL due to the large distances needed to pneumatically pump air typical and typical compressor sizes and threshold velocities for current windmill technology.

[5] In most cases that oxygen transfer from the bubbles themselves is minimal compared with that from the open water surface gas exchange.

no emissions, and generate electricity with no moving parts and little maintenance, making them ideal for remote locations (EPA, 2006).

2.3.2 Physical Treatments

2.3.2.1 Snow Removal

Snow removal has been shown to provide greater light penetration in shallow lakes and enhance the production of photosynthetic organisms, which generates oxygen under the ice. In review of available literature, snow removal is believed most effective over macrophyte beds (Woods, 1961, cited by Fast 1994) and several studies (Paulin 1960) and (Barica, Gibson, & Howard, 1983) have shown that at least 15 to 20% of the surface (130 to 180 ha at URRL) must be cleared to prevent winterkill as noted in Schwalme (1995). Drawbacks of snow removal are large, including labor and equipment expense, difficulty in removing snow during repeated snow falls, drifting over plowed areas, and unsafe ice conditions (Fast, 1994). The remote location of URRL makes snow removal especially problematic.

A second type of snow removal has also been attempted using carbon or coal to increase the albedo of the snow and cause it to melt. This has been shown to be ineffective as it does not work on cloudy days and can be covered by blowing snow (Fast, 1994). In addition, adding carbon could result in a higher demand for oxygen should the carbon accidentally enter the water column. Snow removal by any of the methods above is not believed to be a viable option to reliably achieve the winter DO criterion in URRL.

2.3.2.2 Snow Fencing

Snow fencing can limit wind drift from adjacent areas onto the surface of URRL but does not solve the problem of direct snowfall on the ice-covered lake or other limitations of snow management discussed previously. Furthermore, the annual setup and takedown of snow fence for an unquantified benefit is hard to justify. Consequently, snow fencing is not considered a viable or reliable alternative for URRL and has been excluded.

2.3.2.3 Vegetation Treatments

Macrophytes are widespread in URRL (Paullin, 1973) and oxygen depletion rates of anoxic lakes often correlate to macrophyte biomass (Meding, 2003). Notably, Gangloff (1996) suggest winter DO concentrations in URRL are inversely related to macrophyte biomass such that in low oxygen years, notable growths were observed prior to ice-on. Dead or dying vegetation could be removed mechanically prior to freezing to reduce the oxidative demand of decaying materials. However, it is difficult to quantify the effectiveness of such treatments without full-scale implementation and undertaking such a task on large wide lake is not trivial. As such, vegetation removal was not further considered as an URRL alternative.

2.3.2.4 Ground Source Heat

The use of ground source heat was identified as a potential alternative that could melt ice and create a polynya similar to the aeration options described previously. Direct discharge of water pumped from wells (Fast, 1994) is one possibility, but this would require fossil fuel or electric power installation to the site. Effectiveness would also depend on the quality of groundwater (e.g., temperature and dissolved oxygen concentration). Closed loop pumping systems could also be considered. However, too many uncertainties exist to pursue this approach during writing of this report. We discuss filling certain data gaps with respect to this alternative later in the document.

2.3.2.5 Cutting Holes in the Ice

According to Fast (1994), cutting holes in ice is one of the oldest techniques used to improve overwinter DO. However, the technique has been shown to be ineffective as direct diffusion over the water column through small holes is slow, and the holes quickly freeze over requiring repeated, frequent effort to maintain the opening(s). In addition, because there is no surface turbulence introduced in this approach, except possibly that induced by wind action, much less oxygen is transferred into the waterbody relative to the demand. Accordingly, this alternative does not meet the screening criteria and should not be considered for URRL

2.3.2.6 Molecular Oxygen Addition

The addition of liquid oxygen to prevent anoxia has been implemented at drinking water storage facilities across the United States (Mobley, 2015) and often involves the use of downflow bubble contact aeration systems (e.g., Speece cone, Mobley line diffuser) where the downward or lateral flow of water is directed opposite the buoyant rise of pressurized oxygen bubbles to facilitate oxygen transfer and supersaturate lake water (Schwalme, 1995). Such projects require a stored oxygen source, usually in the form of liquid oxygen (LOx), and oxygen must be added at the rate of depletion. King (1979) described earlier applications of mechanical pumping of compressed oxygen to several small water bodies and concluded that oxygen was a more efficient method than diffused air. Studies of Mirror Lake used both compressed air and pure oxygen, but neither was able to meet the oxygen demand (Smith, Knauer, & Wirth, 1975)[6]. Difficulties with oxygen addition include LOx storage, cost, and delivery, which generally are not conducive to locations such as URRL.

2.3.2.7 Pumping Water onto the Ice/Pump-and-Baffle Aeration

According to Fast (1994), water pumped onto ice-cover and drained back into the lake through holes cut into the ice will melt snow and ice and allow greater light penetration into the lake. At the same time, the water contacts the atmosphere and is oxygenated. However, case studies which apply this approach are seldom successful in improving under-ice DO. Furthermore, once open water is created near the pump discharge point, it down cuts and will not flow over a very wide area, further limiting effectiveness.

A variant of this approach is pump-and-baffle aeration, where lake water is pumped over an incline-plane aerator consisting of a series of baffles. The flow is aerated as it cascades over the baffles. An example of this is shown in Figure 2-4. A primary limitation of this approach in URRL is that baffles would need to be placed at locations meeting the depth criteria of >1 m, i.e., mid lake. Large electrical pumping equipment would also be necessary. This technology is not considered a viable alternative for URRL.

[6] Calculations based on winter oxygen demand of URRL discussed in Section 3.2. They indicate the winter oxygen demand is approximately 700 kg/d, which is a notable limitation of the approach.

Figure 2-4
Example of pump-and-baffle aeration system (Fast, 1994)

2.3.2.8 Fish Population Manipulation

In some cases, fisheries management is used to prevent winterkill (Fast, 1994). Examples of this are liberalized harvest of gamefish in the fall so that fish do not die or contribute to oxygen demand during the winter. As noted in Warren and Jaeger (2017), a variant of the fish population manipulation approach already been implemented in URRL as part of the AMP through removal of competitive fish species in tributaries. This did not provide the desired effect in URRL (Warren & Jaeger, Centennial Valley Arctice Grayling Adaptive Management Plan, 2017). As such, it is not considered a viable alternative for URRL.

2.3.3 Bathymetric Modification

2.3.3.1 Dredging

Dredging refers to the physical removal of accumulated sediments from a waterbody. Common methods include mechanical or hydraulic (i.e., suction) techniques. Mechanical dredging is done under either "dry" or "wet" conditions. The former requires a cofferdam to isolate the region of the lake to be excavated, and then earthmoving equipment such as bulldozers, scrapers, backhoes, or draglines remove the sediment so it can be transported to a disposal site.

Cofferdams can be constructed in a number of different ways including:

- Earthen or rockfill, in which an impermeable (e.g., fabric wrapped) berm is erected around the site;

- Single- or double-walled utilizing a cantilevered sheetpiling barrier;
- Braced consisting of a wooden, concrete, or fabric-wrapped wall to resist the lake water pressure;
- Cellular using straight web steel sheet piles, arranged to form a series of interconnected cells;
- Inflatable bladders filled with water.

Sheetpiling or berms are the most common type of cofferdam. These types would be difficult to construct and expensive at URRL due to its wilderness area designation and remote location. Other proprietary cofferdam systems include Portadams™, which are fabric encapsulated braced wall systems; Big Bags™, which are large dirt-filled bags, and Aquadams™ consisting of water-filled bladders. A system similar to Big Bags™ has been used effectively on The Clark Fork River environmental remediation sites.

Hydraulic dredging or "wet" methods directly remove lakebed sediment without dewatering and are preferred because they are faster than mechanical dredging, create less turbidity, and can effectively remove loose, watery sediments. In most cases, dredging is an expensive means of recovering storage capacity unless the material removed can be used for beneficial purposes. Moreover, studies have been done to evaluate dredging effectiveness over long-term periods. Evidence is generally lacking that it led to the achievement of long-term objectives within projected time frames (National Research Council, 2007). For a detailed account of the URRL dredging alternative, refer to Section 6 of the Preliminary Engineering and Feasibility Analysis.

2.3.3.2 Blasting at Tributary Inlets

Blasting was successfully used to restore the historic channel alignment (reclaimed channel) in Elk Springs Creek and may be an option to implement tributary channel deepening where inlets enter URRL. However, during underwater blasting, material generated from the explosion is not transported anywhere and would require removal just like any other dredged material. Further, blasting can harm or kill fish and also likely impairs water quality. Fish and other wildlife would need to be relocated from the area prior to blasting. As such, this was not considered a feasible alternative and has been eliminated from consideration.

2.3.3.3 Lake Outlet Modification

Increasing lake volume by means of lake outlet modification and/or damming was considered a high-ranking alternative. Dams increase the volume of water and thus the initial oxygen reserve at the time of ice cover. They also reduce the sediment area to lake volume ratio (Mathias & Barica, 1980) which is a primary factor in deoxygenation during winter conditions. Dams can provide other benefits including wildlife habitat, recreation, and water storage, at the same time potentially reducing the frequency of winterkill. For a description of lake outlet modification, refer to Section 6.

2.3.3.4 Lower Lake Dam Operation

During initial stakeholder discussions, Lower Lake Dam Operation was identified as a potential way to modify flow through URRL. Based on details provided during the initial scoping meeting, the maximum pool elevation of Lower Red Rock Lake is two feet lower than the outlet of URRL. Because of this, Lower Lake dam has minimal (if any) effect on URRL water levels or flow velocities. For these reasons, the Lower Lake Dam Operation alternative is not considered viable. It has been excluded from subsequent analysis.

2.3.3.5 Sediment Sill/Groins

It was noted during stakeholder meetings that sediment sills or groins could be constructed to promote underwater scour, or to trap or alter sediment transport. From a conceptual standpoint this does little to improve oxygen levels, and would have to be implemented in conjunction with an alternative like dredging or excavation to provide definitive benefit to URRL. While perhaps providing a benefit to waterfowl or avian nesting habitat, the alternative could increase fish predation by piscivorous birds and is discussed later in the context of dredging and the construction of artificial islands.

2.3.4 Circulation Modification

2.3.4.1 Increase Inflow (groundwater/surface water)

Increasing the lake inflow during wintertime is a simple solution that adds oxygenated water from an external source, thereby directing increasing oxygen loading to URRL. A secondary benefit is realized through increased flushing flow, which reduces the hydraulic residence time. Several tributaries have been identified as potential candidates for this approach as described in Section 5 of the Preliminary Engineering and Feasibility Analysis. The approach is contingent on water right claims and may be difficult to implement under western water law.

Groundwater pumping is another way of increasing inflow, but pumped groundwater may be low in dissolved oxygen. In 2011, USGS conducted an aerial drone survey of URRL attempting to identify ground water upwelling in the lake with thermal imaging. The study was inconclusive, but groundwater expression is apparent in much of the valley wetlands complex. Information on these inflows could be beneficial to understanding DO distribution, or to modifying lake circulation patterns to exploit to increase and/or enhance grayling habitat in such areas. Data collection is recommended before any groundwater modification efforts are considered.

2.3.4.2 Move Tributary Point of Entry (POI)

Diverting water from one or more tributaries (Shambow Pond/Creek, Widgeon Pond, Elk Springs Creek, or Odell Creek) and piping this oxygenated water from the shallow shoreline entry point to the low DO areas at the center of the lake ranked highly in the alternative analysis and is a simple way to achieve the DO criteria at depths > 1 m. The alternative requires field verification of tributary flow rates and oxygen concentrations. Given its simplicity and ease of implementation, it is explored further in Section 5.

2.3.4.3 Restructure Elk Springs Creek at Point of Inflow

Elk Springs Creek originates from springs upstream of the recently restored MacDonald Pond in the northeastern corner of RRLNWR and historically has supported one of Montana's largest Arctic grayling spawning populations. From 1898 to 1908, millions of eggs were taken to create new grayling fisheries (Jaeger, 2015). In 1908, duck hunters diverted Elk Springs Creek from its historic channel into Swan Lake. The historic channel alignment was recently reclaimed in 2016 and now flows directly into URRL. The reconstruction (blasting) left a delta and sediment plug at the confluence with URRL, an area where fish are known to congregate in winter months. Improvements to the channel inlet (e.g., narrow and deepen to increase flow velocity) should potentially be considered for a targeted action, but will not meet the 25 hectare refugia criteria.

2.3.4.4 Develop Springs/pull boards, Impound Tributaries, or Flood Irrigation

Spring developments, tributary impoundments, or flood irrigation modifications were all identified as potential options that could be used to manipulate water exchange or levels in URRL. Several ponds already exist within RRLNWR (e.g., Shambow and Widgeon pond) and these potentially could be used to store water for release during winter months, thereby contributing oxygenated water to URRL during critical times of the year. Such a management option is discussed in more detail in Section 5. The option of impounding other tributaries is believed to not be practicable, and flood irrigation has unquantified benefits; so the latter two alternatives are not considered further.

2.4 Recommended Alternatives

Several alternatives in this section have potential to improve overwinter conditions in URRL, some will simply not work, and others have unknown responses or reliability. Based on these considerations and from the scoring summaries in Figure 2-1, we are carrying the following alternatives into the conceptual design phase:

- Alternative 1 – Mechanical Aeration. This alternative further evaluates the potential for wind, solar, or electrical bubbler/splasher aeration at URRL.
- Alternative 2 – Tributary Diversion & Point of Inflow Modification. This alternative combines tributary inflow modifications with other water management activities on the refuge (e.g., develop springs, etc.) to move oxygenated water from areas that currently do not achieve the depth criteria to locations of the lake that do.
- Alternative 3 –Dredging or Volume Enhancement. This alternative evaluates both dredging and volume enhancement (lake outlet modification) to achieve the AMP depth criterion, which integrates components of artificial islands into the conceptual design.

The above alternatives are detailed in subsequent sections, following a brief description of the regulatory requirements that need to be navigated for each alternative.

2.5 Regulatory Requirements

Any alternative designed to address low dissolved oxygen or habitat constraints for arctic grayling in URRL must comply with federal, state, and local polices and regulations. A listing of federal and state requirements are provided in Table 2-3. General requirements for each act are addressed subsequently, except for NEPA, NHPA, and ESA, which were not included in the scope of work and will presumably be addressed by others.

Table 2-3 Federal and state regulatory requirements that must be complied with at URRL

Act or Policy	Administering Agency
Federal	
Section 404 Clean Water Act (CWA)	U.S. Army Corps of Engineers / Environmental Protection Agency
Section 401 CWA Certification	Montana Department of Environmental Quality (DEQ)
Wilderness Act – Minimum Requirements Analysis	U.S. Fish and Wildlife Service
National Environmental Policy Act (NEPA)	U.S. Environmental Protection Agency
National Historic Preservation Act (NHPA)	Montana State Historic Preservation Office
Endangered Species Act (ESA)	U.S. Fish and Wildlife Service
State of Montana	
Montana Stream Protection Act	Beaverhead Conservation District
Temporary Turbidity (318) Authorization	Montana Fish, Wildlife, & Parks
Montana Pollutant Discharge Elimination System (MPDES) Individual Permit	Montana DEQ

State and Federal compliance with requirements in Table 2-3 must be implemented through the regulatory permitting processes specific to each Act. The level of effort for each permit process is driven in part by thresholds related to the magnitude, timing, and duration of expected impacts. For example, activities that have no, or minimal, adverse environmental impacts may not require a permit at all, while activities with impacts that are intermediate or temporary may qualify for streamlined permitting. In contrast, activities that have large, permanent impacts often require a much more rigorous and time-consuming permitting process. A comprehensive understanding of permitting needs can be developed when detailed, quantitative information is available for each proposed alternative, including the following:

- Construction methods proposed for implementing the project;
- Location and types of wetlands and ecological resources present;
- Areal extent of impacts to streams, wetlands, or other waters of the U.S.;
- Volume, nature, and specific location of discharges of fill;
- Expected impacts to water quality;
- Cultural resources review and potential impacts;
- Threatened and endangered species impacts;
- Whether impacts are temporary or permanent;
- Potential measures to mitigate impacts (including avoidance, minimization, and compensatory mitigation).

Consultation with regulatory agencies is recommended early and frequently throughout the project development process to ensure timely, efficient approval of permit applications.

2.5.1 Section 404 Clean Water Act Permit

Section 404 of the Clean Water Act (CWA) governs discharge of fill material within waters of the U.S., including wetlands. Most, if not all of the URRL project site lies within wetlands or other waters of the U.S. Approval of the discharge may be issued as an individual permit specific to the project, or as a nationwide permit. Nationwide permits are easier to obtain and are issued for common fill activities that require a 404 permit (e.g. installing pipelines, minor dredging, small-scale restoration projects, etc.).

To obtain a permit, the various waters of the U.S. (wetlands, stream, and lake ordinary high-water mark) will need to be delineated within the project footprint to determine their extent and character. Each alternative must then be quantified with respect to its impact. Evaluation of impacts will require information about the selected alternative, such as location and project footprint, the quantity and type of fill being discharged, and whether the impacts will be temporary or permanent. Permanent impacts to wetlands or streams may require compensatory mitigation at a cost of $30,000 to $45,000 per acre of wetland, or $45 to $50 per foot of stream.

Section 404 permits are submitted on a Joint Application that combines several common permits required for work in aquatic environments in Montana (Joint Application Form 270)

2.5.2 Section 401 Clean Water Act Certification

Section 401 of the CWA requires that an applicant for a federal license or permit provide a certification that any discharges from the facility will comply with the act, including state-established water quality standard requirements. This requirement allows states to have input into federally approved projects that may affect its waters (rivers, streams, lakes, and wetlands) and in protecting water quality by applying state water quality standards (http://deq.mt.gov/Water/Permits/401and318). In Montana, Section 401 certification is administered by DEQ as part of the 404 permitting process using Joint Application Form 270.

2.5.3 Montana Stream Protection Act – SPA 124 Permit

The Montana Stream Protection Act (SPA) applies to any project that may affect the natural existing shape and form of the bed or banks of any stream, river, or tributary in Montana. For the URRL project, this would include any impacts to tributaries to, or the outflow from, URRL. The permit applicant must be a Montana state agency, governmental subdivision of the State, or federal agency with a memorandum of understanding with the State, and is administered by Montana Fish, Wildlife, & Parks. Permits are submitted using Joint Application Form 270 and much of the information is the same as required for 404 Permits.

2.5.4 Temporary Turbidity (318) Authorization

For construction activities that are likely to result in an increase in turbidity or release of sediment to State waters, a Temporary Turbidity Authorization is required. State waters include any body of water, irrigation conveyance, drainage facility, or wetland. The permit provides a temporary exemption from water quality standards and is administered by Montana DEQ. For the URRL project, this permit would be required for any construction within URRL, its tributaries, or associated wetlands. The permit application for 318 Authorization is also included in Joint Application Form 270.

2.5.5 Montana Pollutant Discharge Elimination System (MPDES) Individual Permit

Any entity that discharges water to a surface water of the State must obtain an MPDES permit from DEQ. MPDES permits regulate wastewater discharges by limiting the quantities of pollutants to be discharged in compliance with state and federal water quality standards and regulations. A general permit may be issue for common discharge activities, but a more rigorous and comprehensive individual permit may be required for larger or unique discharge activities. DEQ guidance for MPDES permits may be found on the agency's website: DEQ Guidance for MPDES Permitting.

2.5.6 Wilderness Act - Minimum Requirements Analysis

URRL is located within a designated wilderness area, and activities within that area are governed by the Wilderness Act of 1964. Three key sections of the Act influence how activities such as those proposed in this report are managed within wilderness areas. Section 2(a) of the Act provides the context and rationale for the Act, Section 2(c), provides the definition of wilderness, and Section 4(c) provides a list of prohibited uses in wilderness area, except as needed to meet the minimum requirements for the administration of the area. These three sections are excerpted below:

Section 2(a):

"*In order to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition, it is hereby declared to be the policy of the Congress to secure for the American people of present and future generations the benefits of an enduring resource of wilderness. For this purpose there is hereby established a National Wilderness Preservation System to be composed of federally owned areas designated by Congress as "wilderness areas", and these shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness; and no Federal lands shall be designated as "wilderness areas" except as provided for in this Act or by a subsequent Act.*"

Section 2(c):

"*A wilderness, in contrast with those areas where man and his works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value.*"

Section 4(c): (underlining added for emphasis)

"*Except as specifically provided for in this Act, and subject to existing private rights, there shall be no commercial enterprise and no permanent road within any wilderness area designated by this Act and <u>except as necessary to meet minimum requirements for the administration of the area</u> for the purpose of this Act (including measures required in emergencies involving the health and safety of persons within the area), <u>there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area</u>.*"

To conduct activities that might otherwise be prohibited within designated wilderness, Federal land agencies responsible for the management of wilderness areas (in this case, the U.S. Fish and Wildlife Service) must complete a Minimum Requirements Analysis (MRA) to demonstrate that the activity is necessary to meet minimum administration requirements for the area. For example, it may be argued that declines in arctic grayling in URRL are the result of anthropogenic influences and that actions designed to preserve or restore grayling to historic levels are necessary for the administration of the wilderness. Once an action has been demonstrated to be necessary, the MRA process helps agencies to select among competing alternatives the one alternative that is least impactful to wilderness character.

The MRA should lead the reader through a comprehensive, thoughtful analysis that justifies selection of a preferred alternative. For the URRL project, the following materials should be developed:

- A complete chronological history of the management of grayling in URRL. This will provide the appropriate context for describing the problem and justification for the proposed next steps. Important to justification would be any documentation that the wilderness area's condition (e.g. water quality or physical habitat) has been altered by anthropogenic factors that should be addressed to restore the wilderness to its not-altered-by-humans state.

- Justification for completing additional data gathering for the proposed action alternatives in Wilderness. For example, could the testing of the solar aerator be completed in a nearby lake outside of the wilderness? Could the deployment of sediment traps be completed outside of the wilderness area and provide the information needed? If not, the reasons why should be documented. If they can be, then the Wilderness Act requires that they are. This type of approach is also true for the recovery of a sensitive species. If actions can be completed outside of the wilderness area to recover a species, then that should be the first line of enquiry.

- If additional data gathering is required inside of the wilderness area, a separate MRA should be completed for that data gathering activity (versus the MRA for full implementation of the selected alternative).

- Specific implementation steps and methods unique to each alternative need to be developed, and once developed, combined into an overall general implementation sequence for all alternatives. Both of these products are used and evaluated in the MRA.

- An analysis of a No Action Alternative, and a Conforming Alternative that does not involve activities that would violate the Wilderness Act (e.g. carbon addition or manual snow removal) must be considered to justify why the No Action and Conforming Alternatives were not selected, such as failure to meet grayling management objectives.
- A comprehensive analysis of the full range of potential alternatives that demonstrates the selected alternative meets the criterion of being the minimum action required to meet grayling management objectives. This analysis needs to consider the magnitude, duration, and timing of ecological and social impacts for each alternative.
- A person certified to complete a MRA must complete the analysis.

Federal land management agencies have provided guidance to assist with a MRA (see MRA Guidance Homepage). This guidance, called the Minimum Requirement Decision Guide (MRDG), leads the evaluator through a series of questions that relate to the three Wilderness Act sections to determine whether any action is necessary. The following question and descriptions of criteria for determining wilderness character are taken directly from the MRDG instruction manual (MRDG Instruction Manual):

- Are there existing rights or special provisions of wilderness legislation that require the proposed action;
- Is the action necessary to meet the requirements of other federal legislation;
- Is the action necessary to preserve one or more of the five qualities of wilderness character?
    - *Untrammeled* - In wilderness, the "earth and its community of life" are essentially unhindered and free from modern human control or manipulation, "in contrast with those areas where man and his own works dominate the landscape." This quality is important because it helps ensure that wilderness is managed with the utmost humility and restraint, respecting the autonomy of nature that allows a place to be wild and free. It is unlikely that any action is necessary to preserve this quality. In fact, to preserve this quality it may be necessary to cease actions that manipulate "the earth and its community of life" that are not otherwise needed to preserve some quality of wilderness character.
    - *Undeveloped* - Wilderness retains its "primeval character and influence," and is essentially "without permanent improvements" or modern human occupation. Preserving this quality keeps areas free from "expanding settlement and growing mechanization" and "with the imprint of man's work substantially unnoticeable", as required by the Wilderness Act. To preserve this quality, it may be necessary to remove existing structures or installations which are unnecessary for the administration of the area as wilderness or otherwise are not features of the area's wilderness character.
    - *Natural* - A wilderness area is to be "protected and managed so as to preserve its natural conditions." Wilderness ecological systems are substantially free from the effects of modern civilization. Preserving this quality ensures that indigenous species,

patterns, and ecological processes are protected and allow us to understand and learn from natural features. To preserve this quality, it may be necessary to take action to correct unnatural conditions even if they were present at the time of designation.

- *Outstanding opportunities for solitude or primitive & unconfined recreation* – The Wilderness Act defines wilderness as having "outstanding opportunities for solitude or a primitive and unconfined type of recreation." This quality is about the opportunity for people to experience wilderness. The opportunities provided by wilderness include the chance to experience primitive recreation, natural sights and sounds, solitude, freedom, risk, the physical and mental challenges of self-discovery and self-reliance, and to use traditional skills free from the constraints of modern culture.

- *Other features of value* - In addition to the four qualities of wilderness character listed above, which are required of every wilderness, the Wilderness Act says these areas "may also contain ecological, geological, or other features of scientific, educational, scenic, or historical use" that reflect the character of this wilderness. Some of these features, such as the presence of threatened and endangered species, are also part of the Natural quality of a wilderness and could be evaluated for effects to that quality unless the specific species or habitat is not unique to the wilderness area. Other features, however, such as the presence of important geological formations, cultural resources, historical sites, or paleontological localities, do not fit easily into one of the other four qualities. While many different types of features could be included, the intent is to include those that are significant or integral to the wilderness. Features mentioned in wilderness enabling legislation or legislative history would likely qualify. The Other Features of Value that are present must be just as rigorously protected as the other qualities of wilderness character, and so should be accounted for separately. To preserve this quality, it may be necessary to take action to protect these features even if they were already at risk or degraded prior to the date of designation.

The descriptions of the Five Qualities of Wilderness Character (above) are subjective and somewhat emotive, requiring a thoughtful, comprehensive, and thorough analysis to apply them in an objective and defensible manner.

Once an action has been determined to be necessary, the MRDG helps the evaluator to determine the minimum activity required to achieve project goals by developing a list of component actions common to all alternatives and considering activities (methods of implementation) specific to each alternative that achieve those component actions. Examples of component actions and activities for a hypothetical alternative to install solar aerators are presented in Table 2-4.

Component actions and associated activities are rated as having a positive effect (+1), negative effect (-1), or no effect (0) on each of the five qualities of wilderness character. Scores are then summed together to establish an overall rating for each alternative. The MRDG tool concludes with a side-by-side comparison of alternatives that allows the evaluator to select the combination of alternative and activity that accomplishes the goals of the project with the least impact to wilderness character. This is typically the alternative/activity combination with the highest summed score, although other mitigating factors may also be considered to alter the final selection of alternatives.

Table 2-4 Example of MRA evaluation for installing a solar aeration system

Component Action	Activity
Transportation of personnel to the project site	Paddle to site using canoes or row boats
Transportation of material to project site	Helicopter-drop aerator materials at site
Tools used at project site	Non-motorized hand tools for assembly
Condition of site after project	Aerator temporarily anchored to lake bed during winter ice cover

Each of these are considered further in discussion of the alternatives described in Section 4 to Section 6, after a brief overview of the modeling in the next section.

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Section 3

Model Development

Dissolved oxygen (DO) models have been developed to better understand the anticipated response of proposed engineering alternatives in URRL. This work is described below.

3.1 Mass Transport in Ice-covered Lakes

Mixing in ice-covered lakes occurs via several mechanisms including throughflow, sediment-heat generated currents, wind induced seiche (under ice-cover), groundwater upwelling, and convective mixing near the ice-water interface (Bengtssson, 1996; Malm, 1999). Each process is complex and requires a site-specific understanding of waterbody conditions. For this project, the above terms have been lumped into a simplified representation of mass transport: (1) advection (bulk motion), which predominates where velocities are high such as near tributary inflows, and (2) turbulent/eddy diffusion or dispersion that reflects random motions that move mass along the concentration gradient.

According to Ellis and Stefan (1989), most winterkill lakes behave as closed systems with respect to oxygen such that the winter DO concentration is a function of the initial oxygen storage at the time of freezing and the winter DO depletion rate. The latter reflects the combined oxygen loss from bacterial respiration/chemical oxidation at the sediment-water interface (sediment oxygen demand; SOD) and carbonaceous and nitrogenous biochemical oxygen demand (BOD) in the water column. These two oxygen sinks together form the winter oxygen depletion rate.

3.2 Winter Oxygen Depletion Model

Winter oxygen depletion rates were calculated for URRL using the average lake DO data presented in Davis et al. (unpublished) and were verified with data from the winter of 2011–2012. Observations during the winters of 2013 through 2015 indicate a fully mixed water column having DO concentration of about 9.6 mg/L at the onset of ice-on, and a rather steady decline in DO throughout the winter months until rebound occurs in spring (Figure 3-1).

A zero-dimensional (0-D) unsteady oxygen mass balance was constructed to estimate winter oxygen depletion rate ($WODR$) under the following assumptions: (1) that the lake behaves as a continuously stirred tank reactor (CSTR), (2) inflows are known, (3) outflow equals inflow, and (4) no other oxygen sources or sinks exist. The zero-dimensional (0-D) mass balance is as follows (Chapra, 2008)

$$V\frac{dc}{dt} = Qc_{in} - Qc - A \times WODR \quad \text{Eq. 3-1}$$

where V is the volume of the lake (m^3), c is the concentration of dissolved oxygen in the lake (g/m^3), Q is the inflow to the lake (m^3/d), c_{in} is the dissolved oxygen concentration of the inflows (g/m^3), A is the bottom area of lake (m^2, assumed to be the same as the surface area), and $WODR$ is the areal winter oxygen depletion rate ($g/m^2/d$). V in this application is reduced by ice cover where a maximum ice thickness of 0.5 m is assumed to occur on March 1.

Fitting the depletion model in Eq. 3-1 to the Davis (2016) data using the MS Excel® solver indicates that the *WODR* in URRL is approximately 0.06 $g/m^2/d$ at temperatures of approximately 2° C; excluding the unusual February and March observations of Davis[7] or spring ice-off rebound.

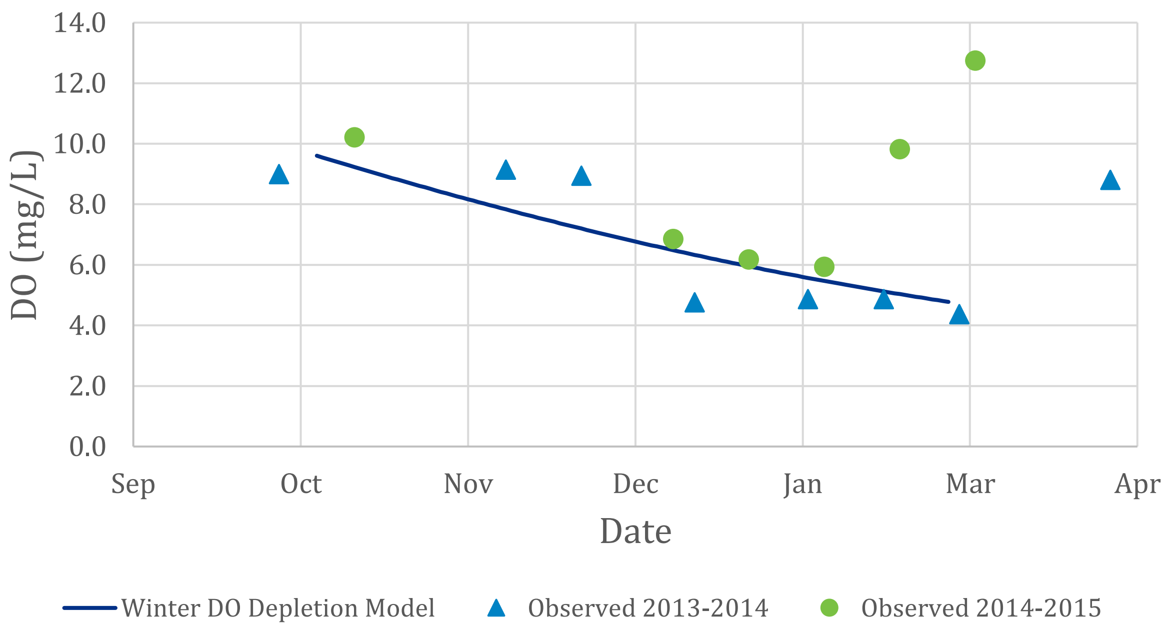

Figure 3-1
Results of CSTR model to estimate winter oxygen depletion rates in URRL

The winter oxygen depletion rate for URRL, relative to other shallow eutrophic lakes, is shown in Table 3-1 for comparative purposes. The calculated rate from Figure 3-1 is low relative to other waterbodies indicating an oxygen source is likely missing in the mass balance. Upwelling groundwater or autochthonous primary production are two possible explanations. Further investigation is required, although it is unlikely that winter oxygen depletion rates differ substantially between URRL and other eutrophic systems.

Table 3-1 Reported winter oxygen depletion rates by Ellis and Stefan (1989)

Source	Combined Water Column/SOD Depletion Rate ($gO_2/m^2/d$)[a]
Babin and Prepas (1985)	0.27
Mathias and Barica (1980)	0.23 (eutrophic), 0.08 (oligotrophic)
Barica and Mathias (1979)	0.27
URRL (2013-2015)	0.06

[a] Rates reflect the temperature of the waterbody and are not adjusted to a standard temperature of 20°C.

[7] The oxygen depletion model in Figure 3-1 uses a low oxygen half-saturation function with a half-saturation constant of 1.5 mg/L (Chapra, 2008). Rates were slightly lower in 2013–2015 than the verification period of 2011–2012.

3.3 Spatial Dissolved Oxygen Model

A simple MS Excel® based two-dimensional (2-D) finite-difference model was developed to simulate the mechanism of turbulent diffusion mass transport of oxygen within URRL and to evaluate potential improvements in the spatial distribution of DO from proposed engineering alternatives. The 2-D time-variable diffusion equation, with a constant point source loading (or sink) term, is written as follows

$$\frac{\delta c}{\delta t} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} + \frac{W}{V} \qquad \text{Eq. 3-2}$$

where c is the concentration of DO in a given control volume (g/m^3), t is time (d), D_x and D_y are the eddy or turbulent diffusion coefficient in the x and y directions respectively (m^2/d), W is a steady-state loading term (g/d), and V is the control volume (m^3) within each segment of the model grid.

During late winter-months after extended cover ice cover, the change in concentration at a given location over time approaches zero (quasi-steady state; refer to historical monitoring data) such that Eq. 3-2 simplifies as follows by assuming that horizontal diffusivity is approximately equal in the x and y directions

$$D_{x,y}\left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2}\right) + \frac{W}{V} = 0 \qquad \text{Eq. 3-3}$$

By applying finite Laplacian differences, Eq. 3-3 can be rewritten as

$$D_{x,y}\frac{c_{i+1,j} - 2c_{i,j} + c_{i-1,j}}{\Delta x^2} + D_{x,y}\frac{c_{i,j+1} - 2c_{i,j} + c_{i,j-1}}{\Delta y^2} = -\frac{W}{V} \qquad \text{Eq. 3-4}$$

Eq. 3-4 can be further simplified by assuming a uniform x and y spatial grid (Δx=Δy). By simplifying and collecting terms the following results

$$c_{i,j} = \frac{c_{i+1,j} + c_{i-1,j} + c_{i,j+1} + c_{i,j-1}}{4} + \frac{\Delta x^2 W}{4D_{x,y}V} \qquad \text{Eq. 3-5}$$

Finally, by recognizing that $V = \Delta x^2 H$, where H is a given control volume's depth (m), the following is used to solve for concentration at interior nodes in the computational stencil (Figure 3-2)

$$c_{i,j} = \frac{c_{i+1,j} + c_{i-1,j} + c_{i,j+1} + c_{i,j-1}}{4} + \frac{W}{4D_{x,y}H} \qquad \text{Eq. 3-6}$$

The equation above can readily be computed across a grid in MS Excel® using iterative calculation procedures. Modifications to this equation to accommodate no flux boundary conditions at exterior corner and edge nodes are required and are detailed elsewhere (Edwards & Lobaugh, 2014; Mahmud, 1996).

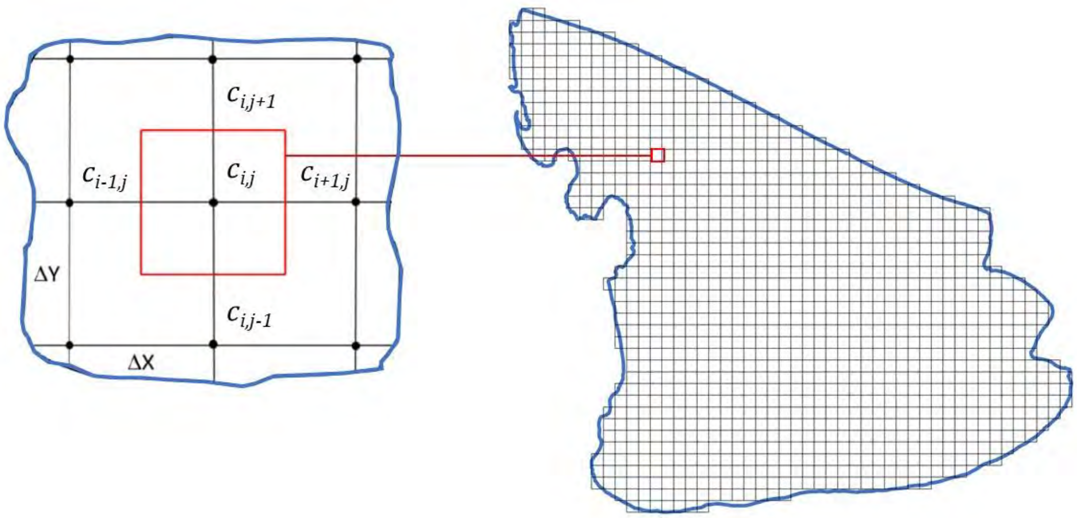

Figure 3-2
Computational stencil used in implementation of the 2-D oxygen dispersion model

The 2-D model of URRL in Eq. 3-6 is parsimonious, requiring knowledge of just a few terms. The model grid size (Δx, Δy) and grid depth (H) are physical defined, tributary boundary conditions can be measured, and the combined sources and sinks of oxygen in URRL (W) are reflective of the net winter oxygen demand described previously. This leaves only the turbulent horizontal diffusion coefficient (D_{xy}) to be calibrated.

3.4 Mixing Zones

Certain locations in the model grid are subject to both advective mixing and dispersive transport. As such, the diffusion transport equation is not fully valid. To correct this deficiency, mixing zones were defined by identifying Dirichlet boundary conditions over the portion of the model grid where the aggregate control volume concentration is refreshed daily (i.e., hydraulic residence time of one day), essentially scaling the mixing zone in proportion to the incoming tributary flow rate and the mean depth of grid where the mixing zone occurs. Concentrations were assumed to be at saturation in these locations (e.g., ca. 10 mg/L at an elevation of 6,615 ft at 4°C).

3.5 Model Calibration

The 2-D dispersion model was calibrated to data collected during previous winters at URRL. Because the model is steady-state, and only late winter critical conditions are applicable, a subset of the overall dataset was used in calibration. Observations from 1995 through January 2019 were compiled to identify the most appropriate period (Figure 3-3), noting that February samples have a tendency toward low low-oxygen conditions. Data in this month were used to constrain the model. Spatial results of the 2-D dissolved oxygen model results for URRL are shown in Figure 3-4. Observed versus simulated results are shown in Figure 3-5.

Model fits (noting the 1:1 line) are less than desired and produce root mean squared error (MSE) of 1.9 mg/L. They generally capture the spatial distribution of oxygen in URRL discovered in previous monitoring campaigns (Davis, McMahon, Cutting, & Jaeger, unpublished) (Kyle Cutting, personal communication). Better fits can be achieved through increases in the horizontal dispersion coefficient, although as noted later, this is not physically justified.

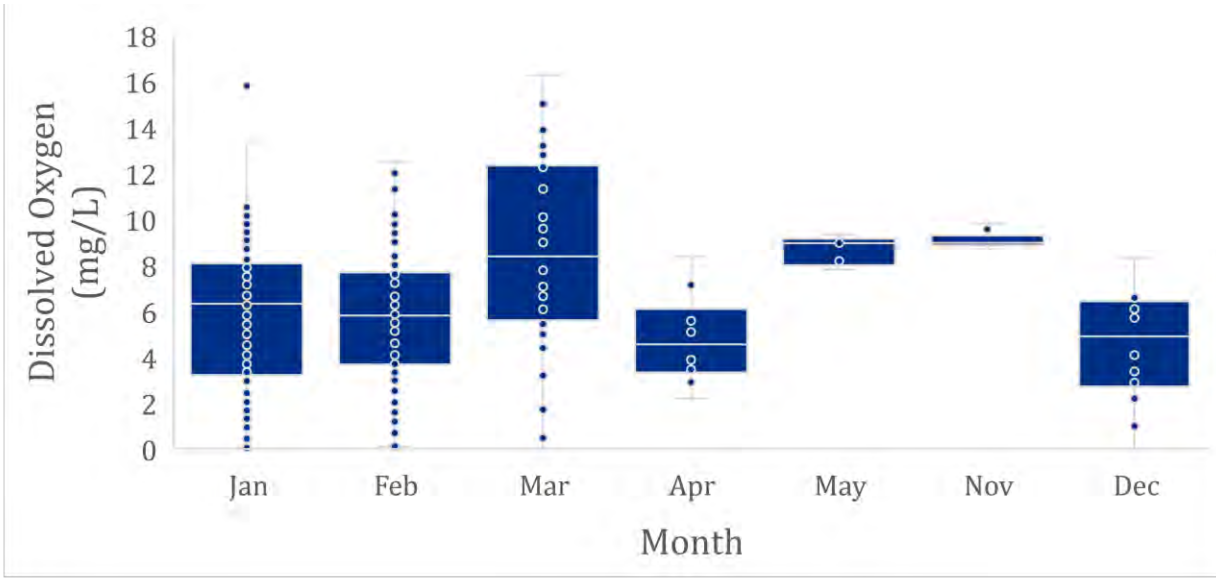

Figure 3-3
Boxplot of oxygen conditions observed in URRL at depth of 0 m (1995–2019)
February experiences some of the lowest DO concentrations (median <6 mg/L).

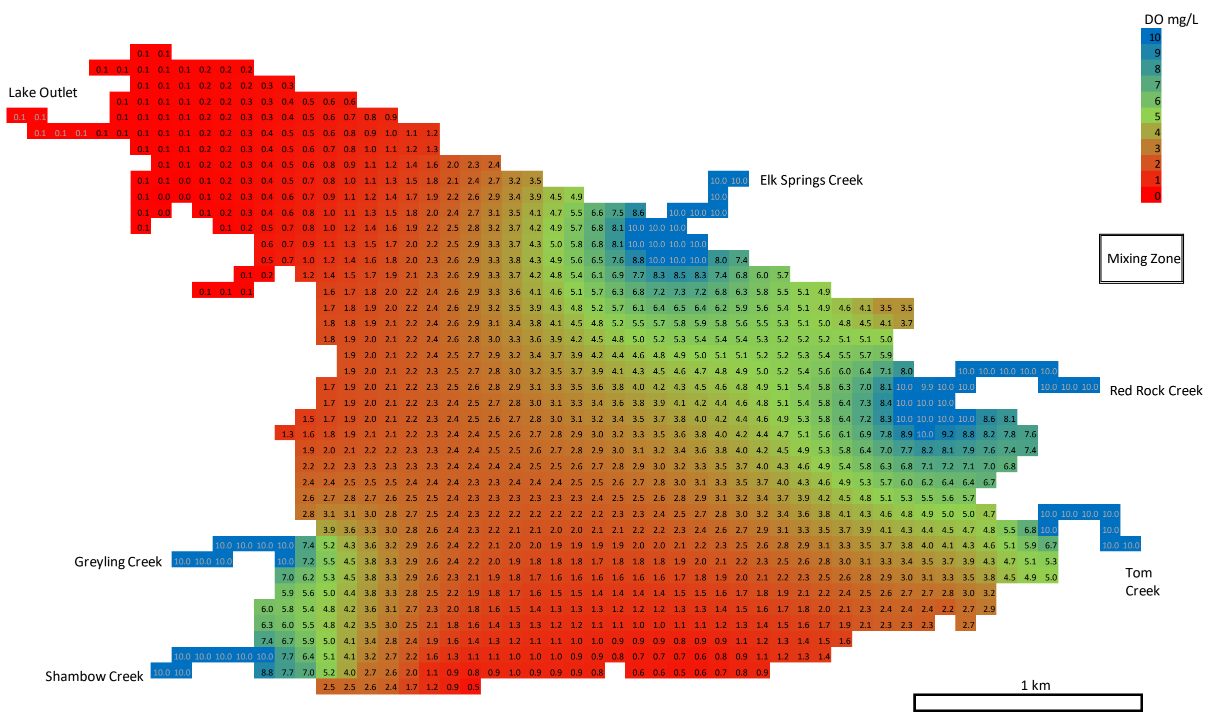

Figure 3-4
Results of the 2-D oxygen calibration for URRL during late winter conditions

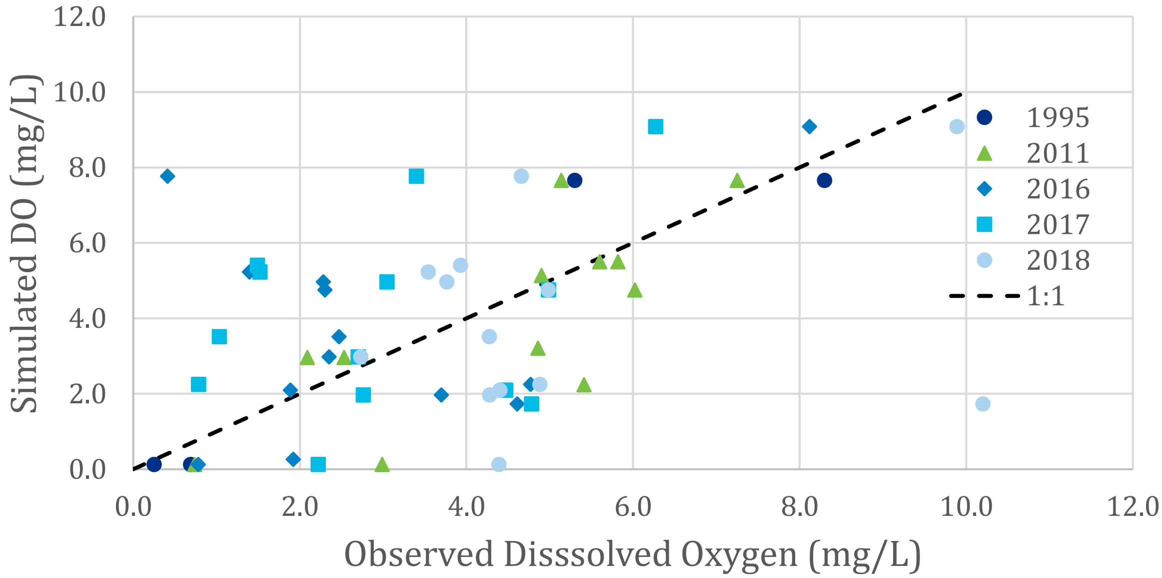

Figure 3-5
Model fit for the 2-D DO model during late winter conditions

The years of 1995, 2011, 2016, 2017, 2018, and 2019 were evaluated in calibration as they do not meet the minimum winter area habitat criterion (Centennial Valley Arctic Grayling Adaptive Management Project Annual Report 2018, 2019).

Results were verified through a review of literature on ice-covered lakes. Malm (1999) indicate horizontal dispersion coefficients in winter studies span several orders of magnitude, sometimes approaching those found in ice-free lakes. Published values are shown in Table 3-2. As noted in the table, the calibrated URRL value approximates ice-free conditions (Chapra, 2008), which may indicate another mechanism is enhancing mixing beyond what is typically experienced in ice-covered lakes. It is possible that this is related to the lake's shallow depth (e.g., convective cells occurring near the surface and bottom simultaneously) or advective flow through the lake that results in greater mass transport than eddy dispersion alone.

Table 3-2 Reported horizontal diffusivities in ice-covered lakes

Source	Horizontal Dispersion Coefficient	
	(cm^2/s)	(m^2/d)
Coleman and Anderson (1983)	0.47	4
Bengtsson (1986) river-flow dominated seiche-induced	1.0 10–120	86 1,037
Chapra (2008) – ice free	$10–10^6$	$430–10^7$
URRL	868	7,500

3.6 Model Implementation for Minimum Winter Habitat Area Prediction

The URRL 2-D DO model can be used in a predictive capacity to evaluate winter habitat conditions. An example of this is shown in Figure 3-6, noting that the calibrated model operating under average environmental conditions has 16 ha of winter habitat using the dissolved oxygen concentration criterion of > 4 mg/L and depth of >1.0 m. To achieve the desired 25 ha of habitat, an engineering alternative is required that will increase the modeled habitat by 25 ha, or in this example, increase the modeled minimum winter habitat area from 16 ha to 41 ha. This approach inherently acknowledges model prediction bias, noting that during critical conditions habitat likely approaches 0 ha.

With the above understanding, it is important to point out that there are physical restrictions on the spatial location of habitat due to its definition (i.e., > 1 meter of depth). Only locations in the central basin of the lake achieve the depth criteria during late-winter ice-cover (delineated by black polygon in Figure 3-6; assuming ice cover of 0.5 m). This limitation will be discussed in subsequent sections and presents an engineering challenge due to the size of the lake and distance from the shoreline.

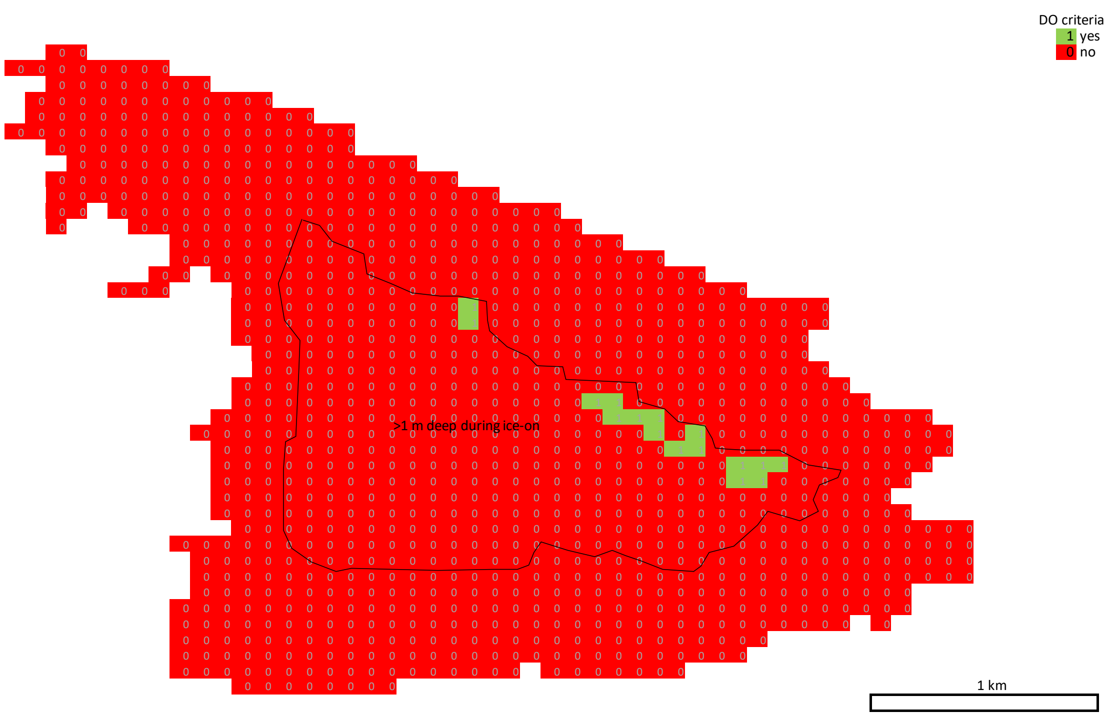

Figure 3-6
Simulated minimum winter habitat area from the 2-D URRL model

3.7 Model Limitations

It should be recognized that the 0-D winter oxygen model and 2-D spatial model described in this section are simplified and imperfect representations of URRL. Neither tool fully represents the complete spectrum of mechanistic processes involved, nor does either model provide ideal fits when compared with observed data. Moreover, boundary condition and model input data are uncertain (approximated in several cases), and calibration coefficients are perhaps outside of the range typically experienced in ice-covered lakes (despite fitting the observed data). Finally, as one might expect, very little can be done through calibration using a single parameter. As such, the results and associated conclusions made with the model(s) in this report should be used with caution. More robust modeling techniques should perhaps be considered in the future.

Nonetheless, the mechanistic modeling tools described in this section provide a way to understand the effects of management actions before they are implemented, and also help us to understand certain lake processes on a simplified level. When combined with empirical data and models discussed in subsequent sections, they provide a useful line of evidence for understanding cause and effect relationships in URRL.

Section 4

Alternative 1 – Mechanical Aeration

Aeration by electric, wind, and solar power all ranked highly in the alternative screening and have been shown to be useful for mitigating anoxic or hypoxic oxygen conditions in ice-covered lakes or reservoirs by disturbing ice cover and disrupting vertical density stratification. This section discusses site design conditions specific to URRL in the context of aeration to provide a recommendation for the site.

4.1 Electric Aeration (via Conventional Grid Tie)

Due to its remote location and wilderness designation, URRL does not have electrical power. Establishing an electrical service is therefore required for any alternative needing a dedicated power supply. The nearest electric utility connection is 3.31 miles to the west near the town of Lakeview along the road alignment at the intersection of S. Valley Road and a private road that serves a residence (John Taft) in Odell Creek (Rich Ferris, personal communication March 2019). Assuming a take-off from this location, the proposed direct-bury underground alignment would follow the right-of-way on South Valley Road through the existing wilderness to the non-wilderness campground on the south shore of the lake (Figure 4-1).

Vigilante Electric Cooperative is the service provider in this area and was contacted to identify the available supply and provide a verbal quote regarding electric installation cost (Rich Ferris, personal communication March 2019). Single phase power is available and can operate 10 to 15 HP worth of aerators or compressors. At the quoted rate of $25,000 per mile, and assuming no easement issues in the roadway, ditch, and campground alignment, the cost to supply power to URRL, including a co-op membership fee, is approximately $85,000 for the completed new-service installation. This is believed to be a very reasonable cost given the remote location.

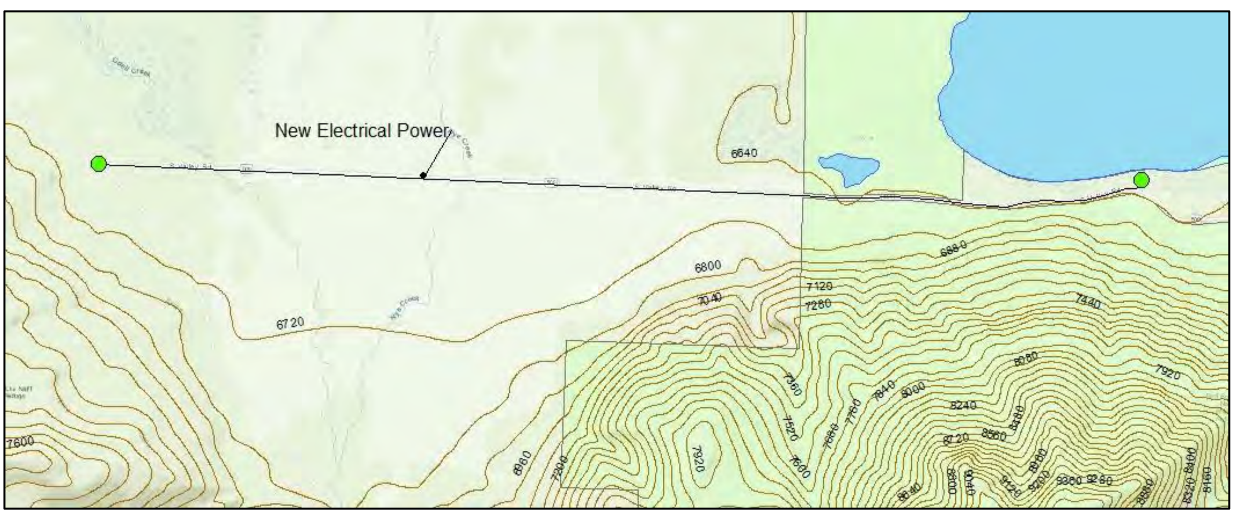

Figure 4-1
Electrical transmission route and alignment to URRL from the existing take-off

URRL has a large surface area, which is challenging when ice thickness is at its maximum since locations >1 m deep are over one mile (5,780 feet) from the southern non-wilderness shoreline. High-powered electric surface aerators cannot be located far offshore (Ashley & Nordin, 1999) given submersible electric cable length limitations (or pneumatic hose length for compressed air systems). For single-phase power such as present near URRL, the distance the aerator unit can be placed from the electrical service connection is a function of the maximum length of submersible electrical cable for a given voltage and horsepower rating. General recommendations for single-phase motors are shown in Table 4-1.

Table 4-1 Allowable copper wire electrical cable length (Franklin Electric, 1980)

Voltage	Motor Rating (HP) [a]	Copper Wire Gage						
		12	10	8	6	4	2	0
115	0.25	263	411	645	1000	1540	2340	---
115	0.5	159	249	390	608	930	1410	1910
230	0.25	1040	1650	2580	4020	6140	9355	---
230	0.5	641	1003	1575	2450	3750	5710	---
230	1.0	392	617	968	1507	2300	3510	4730
230	1.5	326	510	801	1248	1920	2930	3950
230	3	229	359	563	877	1339	2041	2750

[a] Single-phase power with lengths in feet, HP = horsepower

As indicated above, very large (0 AWG gage wire) is required to reach distances approaching one mile for a 1 HP aerator, with a maximum distance of 4,730 feet. A single dedicated submersible electrical wire is therefore required per electric aerator. 1/0 AWG gage submersible electrical wire is approximately $9.20/ft such that the cost of the project is driven by the amount of dedicated submersible cable required to serve each aerator.

McCord and Shladow (2001) provide guidance on estimating the number of electric aerators for an aeration project. A waterbody-specific dimensionless term relating water depth at the aerator to surface aerator energy and distance of influence of the splasher (M) must first be established

$$M = \frac{0.32H^{5/6}}{Q^{1/3}} \qquad \text{Eq. 4-1}$$

where H is the depth of water (m) and Q is the flow rate of the splasher (m^3/s). According to McCord et al. (2000), the typical flow rate of a 1 HP splasher is 0.093 m^3/s.

A second term (M^*) must also be developed that relates the localized splasher influence to the overall lake surface area

$$M^* = \frac{MA^{1/2}}{nH} \qquad \text{Eq. 4-2}$$

where *A* is the lake surface area (m^2) and *n* is the total number of independent locations where splashers are located.

Using site-specific information from URRL (e.g., depth of 1.5 m during ice on and minimum surface area of 25 ha), the number of 1 HP splashers required to stay within the "ideal design region" from Eq. 4-1 and 4-2 is two (Figure 4-2). This indicates each aerator can serve approximately 12.5 hectares or 30 acres. A third aerator was included for design purposes, noting URRL will likely behave differently than the whole lake applications in the literature (e.g., while only 25 ha is being aerated, the lake surface is much bigger). Problems associated with under or overdesign based on the dimensionless quantities established previously are identified in Table 4-2 (e.g., overcooling or sediment resuspension), .

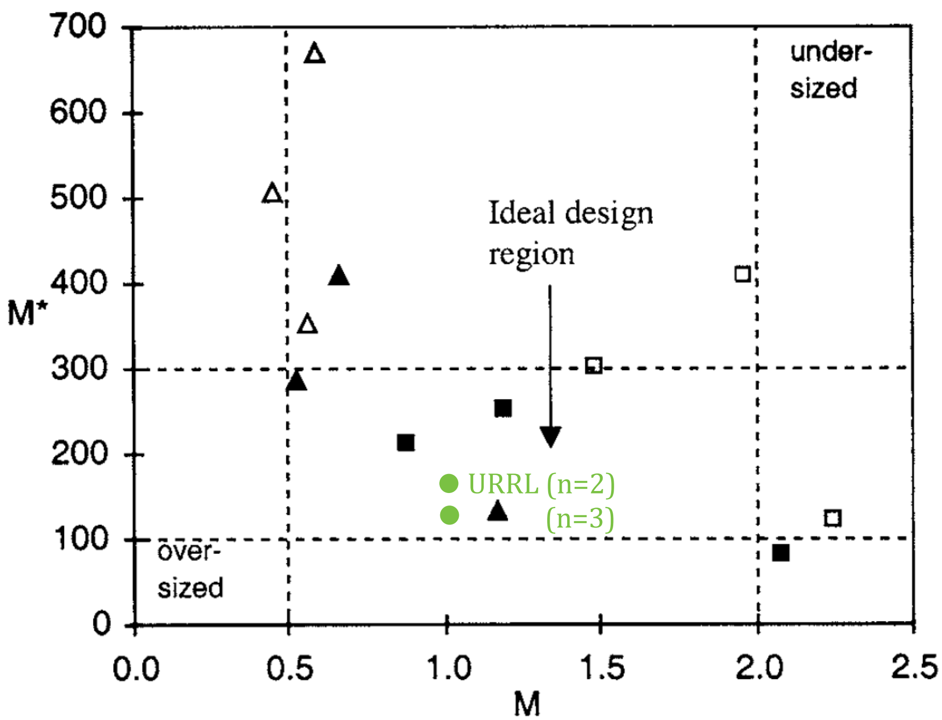

Figure 4-2
Recommended aeration design parameters *M* and *M for Wisconsin lakes**

Table 4-2 Design criteria for splasher aerators under ice cover (McCord & Schladow, 2001)

Parameter (design range)	Lower than design range	Within design range	Higher than design range
M (0.5-2.0)	Aerator will disturb the sediments, possibly stirring up organic material and unnecessarily increasing BOD	Well-sized for depth of water	Aerator is too small for the depth of the lake. It may need to be relocated to shallower water, or additional units used
*M** (100-300)	Water temperature may drop to near freezing. Near-shore water will be well mixed	Maintains a reasonable DO level throughout the mixed depth	The entire lake area may not be adequately aerated.

Aerator sizing requirements can also be approximated by examining empirical data. Fast (1994) provide a compilation of data for Minnesota lakes originally published by Pederson (1982) that are shown in Figure 4-3. They indicate that 18 HP of aerator capacity would be required to fully aerate URRL. However, to aerate the 25 ha minimum area requirement, a smaller system could be used, on the order of 2 HP. It is important to note that Pederson (1982) indicate that there are no simple guidelines to size aeration systems, and the engineering design of pneumatic aeration systems is lake-specific[8].

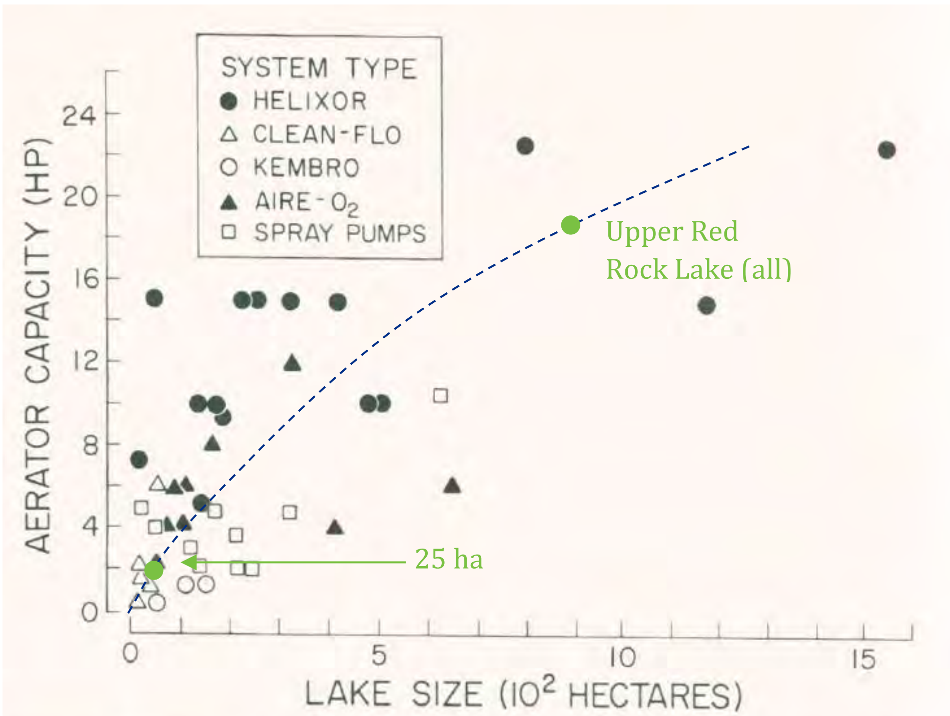

Figure 4-3
Relationship between lake size and lake aeration capacity (Fast, 1994)

Just like electric aerators, pneumatic bubble aeration systems also have limitations including the distance of tubing from the compressor, and how many diffuser ports can be placed on each line. Typical manufacturer recommendations indicate a maximum distance of 2,000 to 5,000 feet from the compressor, and the theoretical maximum for a 0.75" ID weighted tubing, by limiting the pressure drop to 20% or 5 psi from the compressor for a flow rate of 5 CFM is approximately 5,000 feet (to overcome friction losses in the tubing). Compressors could potentially be mounted on a mobile trailer and moved on- and off-site each season, keeping the primary disturbance to the non-wilderness area near URRL.

Benefits of electrical (grid-tie) based aeration are summarized as follows:

[8] The surface polynya created during aeration depends on application, air temperature, site wind speed, and volumetric flow rate of air. As a rule of thumb the diameter is roughly twice that of the depth. Based upon a six-foot maximum depth, the surface polynya area per diffuser will likely be 12 feet in diameter and 113.10 square feet (0.0026 acres) of open water.

- Reliable power source and continuous operation; widely used in many lake aeration applications;
- Tangential benefit of having power at the lake campground for future use;
- Relatively low expected maintenance;
- Robust, quantitative design guidance;
- Existing systems successfully installed in Montana (Montana Fish and Game, 1964).

Limitations and/or risks include:

- Initial costs including electrical power service, tubing, or submersible cables;
- The length of submersible cable or tubing restricts how far from shoreline the aerators may be placed;
- Compressors are noisy/unsightly in the campground for winter recreation;
- Impacts to wilderness designation.

4.2 Wind Aeration

Windmill aerators are one of the oldest options available for aerating small ponds or lakes. They use the force of oncoming air currents to turn blades of a head that drive an internal rotor, which is connected to a generator, compressor, or direct drive aerator. Research into their use was initiated in the 1970s (Schierholz, Somervell, Babcock, Hartel, & Timbre, 1975) for sites without electricity. Windmills typically have cut-in speeds from 3 to 6 mph (1.3 to 2.7 m/s), which is the velocity required to turn the head of a small system under low backpressure situations. Higher speeds are needed if the diffusers are placed in deeper water or longer distances from the windmill (Table 4-3). Some of the largest standard compressors manufactured can only move air up to 1,000 feet; the URRL application requires over five times this distance.

Table 4-3 Threshold velocities required for wind aeration

From Schierholz et al. (1975)

Windmill Type and Diameter	Lake Depth at Bubbler (m)	Bubbling System	Threshold Velocity or Cut-in Speed (m/s)
Aeromotor (3.1 m)	0.97	1 Helixor 2.5 cm polypipe	2.2–2.7
Aeromotor (3.7 m)	1.4	Irrigation pipe 3.8 cm poly	5.4–5.8
Aeromotor (2.4 m) and AWT (2.4 m)	1.5	Irrigation pipe 3.8 cm poly	4.0–4.5
2 @ Aeromotor (1.8 m)	2.5	1 Helixor 1.9 cm polypipe	1.8–2.2

In assessment of the limitation above, winter wind data from 2009 through 2019 (October–March) from the Red Rock Remote Automated Weather Station (RAWS) site RRDM8, located three miles north of Lower Red Rock Lake, were downloaded to provide a local estimate of wind speed near the project site (MesoWest, 2019). The average velocity over the analysis period was 6.49 mi/hr (2.90 m/s) with wind blowing from north-northeast (Figure 4-4)[9]. Assuming the data are transferable to URRL, nearly half of the wind measurements are less than 2.5 m/s and will not keep the head turning or provide enough torque to be reliable for application. There appears to be insufficient wind power at URRL to power a windmill at full capacity.

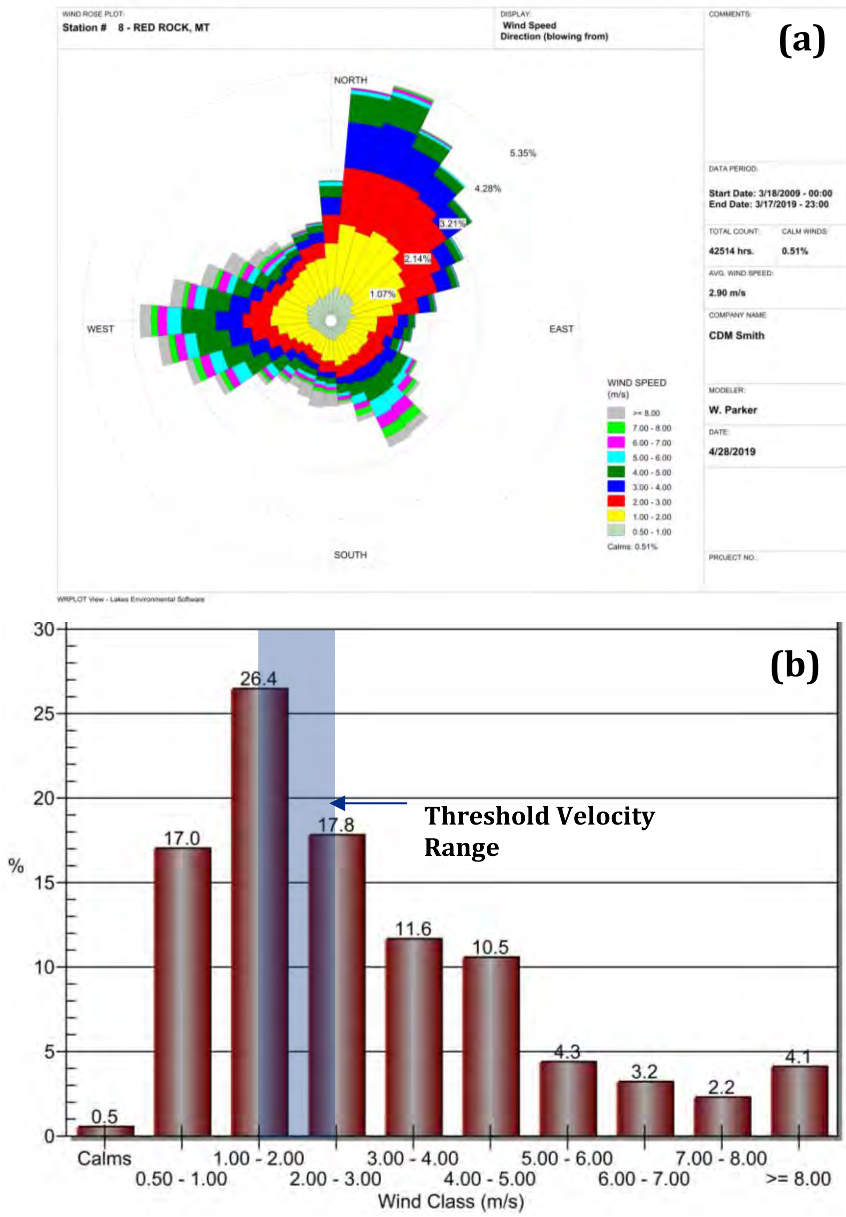

Figure 4-4
Wind information for RAWS RRDM8 observations (2009-2019)
(a) Wind rose plot. (b) Wind class frequency distribution. Located in Centennial Sandhills, Montana. 3 miles to the northwest of URRL; assumed to reflect URRL site conditions.

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[9] The RRDM8 weather observation station is 75 feet higher in elevation than that of URRL and 3 miles away. It may not fully represent site conditions. We did not correct for power wind law, or for different canopy roughness.

Benefits of wind power aeration are as follows:

- Low operation cost and renewable;
- No electrical connection required;
- Existing systems successfully installed in similar scenarios.

Risks and/or limitations include:

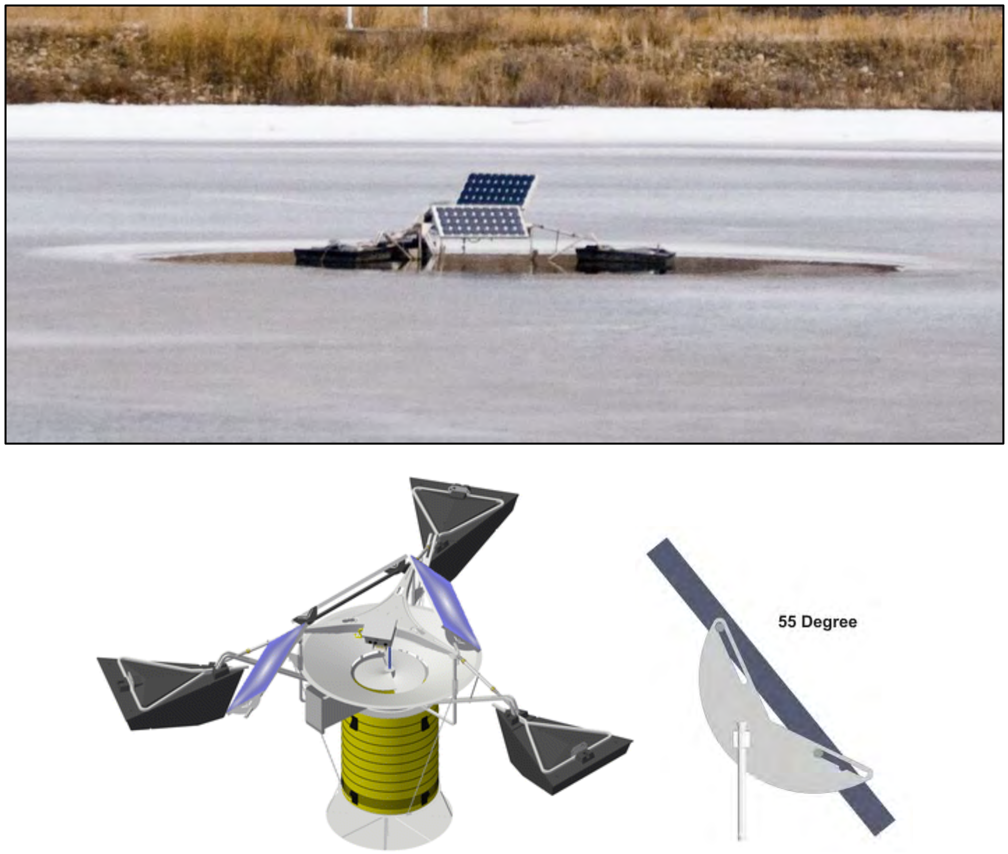
- Insufficient windspeed to fully power compressors;
- Requires the presence of a steady source of wind to operate;
- Many units are required, and may not be aesthetically pleasing to the eye;
- Windmills can be damaged by powerful gusts and/or storms;
- During winter operation, condensation can build up on the inside of the air tubing near the shoreline causing increased backpressure and compressor failure;
- A windmill set in the lake on pilings could sustain ice damage in the spring.

Based on the understanding above, wind powered aeration at URRL is not recommended.

4.3 Solar Aeration

Solar aerators have received recent attention due to technological advancements in photovoltaic (PV) panels and battery storage. While solar powered aerators and mixers include many of the same features and components as wind and electric aeration systems, the main difference is that the energy is derived from the sun and is renewable. Solar aerators consist of three general components: (1) PV modules that gather light and convert it into electricity, (2) battery storage, and (3) the mixer. Advancements in solar energy technology have greatly improved the efficiency and reliability of solar power, and solar aerating systems today store excess energy in battery back-up systems, which lessen the chances for periods of inefficient operation (e.g., cloudy days) or when power is not available (e.g., nighttime).

In 2001, SolarBee Inc. (now Medora Corporation) developed the SolarBee® mixer (Figure 4-5), which is a floating solar circulator that can effectively aerate a small ice-free 25-acre lake (EPA, 2005). The SolarBee® is an updraft, low head, high volume axial pump, designed to circulate large volumes of water (up to 10,000 gpm) in reservoirs and lakes. The unit possesses six days of battery storage for up to 24-hour operation, which is beneficial during low sunlight conditions. It is powered by three mono-crystalline 90W photovoltaic modules totaling 270 watts (W) that do not require direct sunlight. Electronic logs from existing machines show they run 24-7, year-round, at 98% full speed in most of the U.S. including many locations that experience inclement weather.



(a)

(b)

Figure 4-5
Close up photograph of a SolarBee® solar mixer in a winter lake application
(a) Showing the polynya (Photo credit: Water Logistics). (b) 3-D drawing of floats and draft tube with oblique view of panels with winter orientation.

A single SolarBee® machine's intake can be set to mix only the top three feet of water without disturbing the bottom three feet, which minimizes sediment resuspension. Each machine has an encased anchor and 50-foot chain allowing for movement to prevent damage by ice or wind. The aerator can be moved on or off the lake by boat, if needed, during summer months. During periods of prolonged inclement weather, should the machine fail to operate for an extended period and become frozen into the lake ice, freeze sleeves on the impeller shaft allow the shaft to turn freely inside the sleeve to wash out surface ice until the machine starts back up following the nonoperational period. No damage to the electrical components, machinery or floats occurs when this happens.

Solar potential of the site was assessed using the RAWS RRDM8 station discussed earlier. The average of all hourly observations over the last ten winters results in a daily flat plate solar radiation of 122 W/m^2. The daily average for winter solstice is 62 W/m^2. The motor's operating power is 40 to 50W. Based on discussions with the manufacturer, there will potentially be enough watt-hours to power the motor throughout the day and into the night at reduced speeds, although augmentation with a small supplementary power source (wind) may be necessary. Three solar mixers will be necessary to generate 25 ha winter habitat in URRL.

Benefits of solar aeration include:

- Renewable resource;
- Inexpensive in comparison to other alternatives;
- Unit rental program allowing for a pilot study;
- Infrastructure located in the target habitat area and not on shore;
- Relatively low expected maintenance.

Risks and/or limitations are as follows:

- Limited solar resource at the project site;
- Solar intermittency;
- Chance of snow accumulation on the panels;
- Units may need to be removed during summer months;
- Potential damage by ice during breakup;
- Potential limitations due to shallow water operation;
- Risk of increased SOD due to circulation and potential for resuspension of sediment.

4.4 Costing and Preferred Aeration Option

Ashley (1987) indicate the best solution for aeration systems are those that have relatively low initial cost, and low operation and maintenance requirements. We have reached out to vendors to provide quotes for costing purposes, or consulted manufacturer pricing, with the goal of achieving general costs and sizing of materials, transport, and installation. An Opinion of Probable Construction Costs (OPCC) commensurate to a Level 5 accuracy for each of the aeration systems after conceptual design for URRL are summarized in Table 4-4 (detailed in Appendix C). Limitations such as site access and wilderness designation, permitting, technology performance evaluation and initial pilot testing, and operation and maintenance, are not included in the cost estimate. They are discussed at the end of this section however.

Table 4-4 Estimated costs of mechanical aeration at URRL

Aeration Type	Estimated Option Cost ($) [a]
Bubbler	$280,333
Splasher	$269,959
Wind	$299,610
Solar	$145,299

[a] Including 10% contingency; estimates do not include O&M (e.g., cost of monthly electrical usage).

The OPCC includes material, labor and equipment. Estimates do not cover probable total costs including design, project administration, permitting, and pilot testing. The pricing noted in Table 4-4 is higher than that presented by Ashley (1987)[10], but still clusters with some of the more expensive applications requiring long powerlines or diesel generators (Figure 4-6).

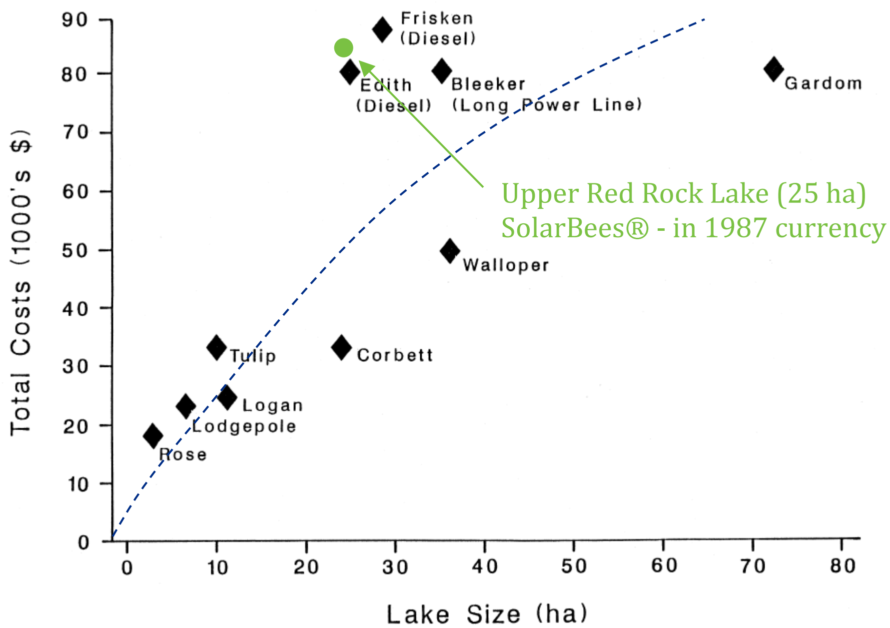


Figure 4-6
Total cost of aeration systems reported previously in 1987 dollars (Ashley, 1987)
Currency adjustment from U.S. to Canadian dollars (1 USD to 1.35 CAD). CPI from Bureau of Labor and statistics at https://data.bls.gov/cgi-bin/cpicalc.pl

Based on the information above, we feel that solar powered aeration is likely the best aeration alternative that will limit on-the-ground infrastructure (e.g., no compressors, air tubing or electrical cable, or windmills), is the lowest initial cost and risk, and may present the least wilderness site impacts as panels could potentially be removed or camouflaged during the summer monthly making the equipment less intrusive. Moreover, its operational requirements, rental program (try before you buy), and renewable basis are attractive. Concerns still exist about its performance capability during winter months (it is possible that a supplementary power source may have to be added in the form of a 100-400 W wind turbine mounted on the SolarBee®) and the potential risk of increased SOD and/or sediment resuspension due to circulation will have to be carefully assessed through performance monitoring.

Medora has quoted a price for three solar-powered SolarBee® mixers, spaced at 25 acres per unit, totaling $145,299 including equipment, factory delivery, placement and startup. However, the more interesting aspect of their services is their rental program. Equipment rental costs for 12-months total $20,930 for a single unit, including factory delivery, placement and startup. In this regard, six months' rental would cost approximately $13,214 for one unit. The rental would allow

[10] After accounting for inflation according to the consumer price index (CPI) which indicates a 122.6% increase over time.

for a pilot study to be conducted using one unit to monitor performance. At the end of the study, the equipment could be purchased (rental cost applied to cost of purchase), continue to be rented, or returned. Medora would pay the retrieval cost.

4.5 Modeled Response and Other Considerations

Model results for the conceptual design of an application using three SolarBee® units in URRL are shown in Figure 4-7. Predicted habitat is estimated to be greater than 25 ha, and we have assumed the average mixed concentration at the aerator is the mean of the atmospheric concentration (assumed to be 10 mg/L, conservatively) and zero at the bottom of the lake (indicative of a large SOD from the sediments). In this regard, the alternative appears to extend contiguous habitat across URRL, connecting the natural suitable habitat in the northeast and southwest parts of the lake, thus providing meaningful improvement.

Results should be viewed with caution however because (1) predicted concentrations are very near the 4.0 mg/L habitat criterion threshold, (2) unexplained model variation (RMSE) is larger than desired (see Section 3.0), and (3) diffusivities used in the model calibration are outside of those typically measured in ice-covered lakes (though the calibration fits the existing observed data). It is also important to note that URRL will likely respond differently than whole lake applications discussed previously because URRL will have a significant volume of water outside the aeration zone that is oxygen deficient. This will exert a demand that may lead to performance issues outside of those recognized in the literature.

As noted by many prior investigators, caution should be exercised when implementing aeration. The following should be carefully examined during operation if the aeration alternative is chosen:

- Heat loss. A properly designed aeration system can create a large opening in the ice and result in significant cooling and unknown effects to lake biota. Unusual fog and frost patterns can result (Ashley & Nordin, 1999). It is recommended that a real-time temperature monitoring program be implemented to be sure that lake temperature remains within acceptable levels.

- Accidental deoxygenation. According to Fast (1994), special care must be used when commencing aeration in late winter, especially when DO levels near the sediment-water interface have declined to <3 mg/L, as velocity induced reductions in the thickness of the diffusive boundary layer enhance oxygen mass transfer across the sediment-water interface. Aeration in these circumstances may accelerate oxygen depletion and cause winterkill rather than prevent it. This is particularly true of aeration systems that cause extensive water mixing. Real-time monitoring of dissolved oxygen levels is strongly recommended using a sonde and satellite communication to ensure this does not occur.

- Sediment generation. Aeration or mixing systems that suspend bottom sediments can have disastrous effects on DO concentrations in ice-covered lakes due to increased water column biochemical oxygen demand. Real-time turbidity monitoring should be completed in addition to the oxygen monitoring discussed previously to ensure sediment is not being resuspended during aerator operation.

We propose a performance monitoring program in Section 7 to address these concerns.

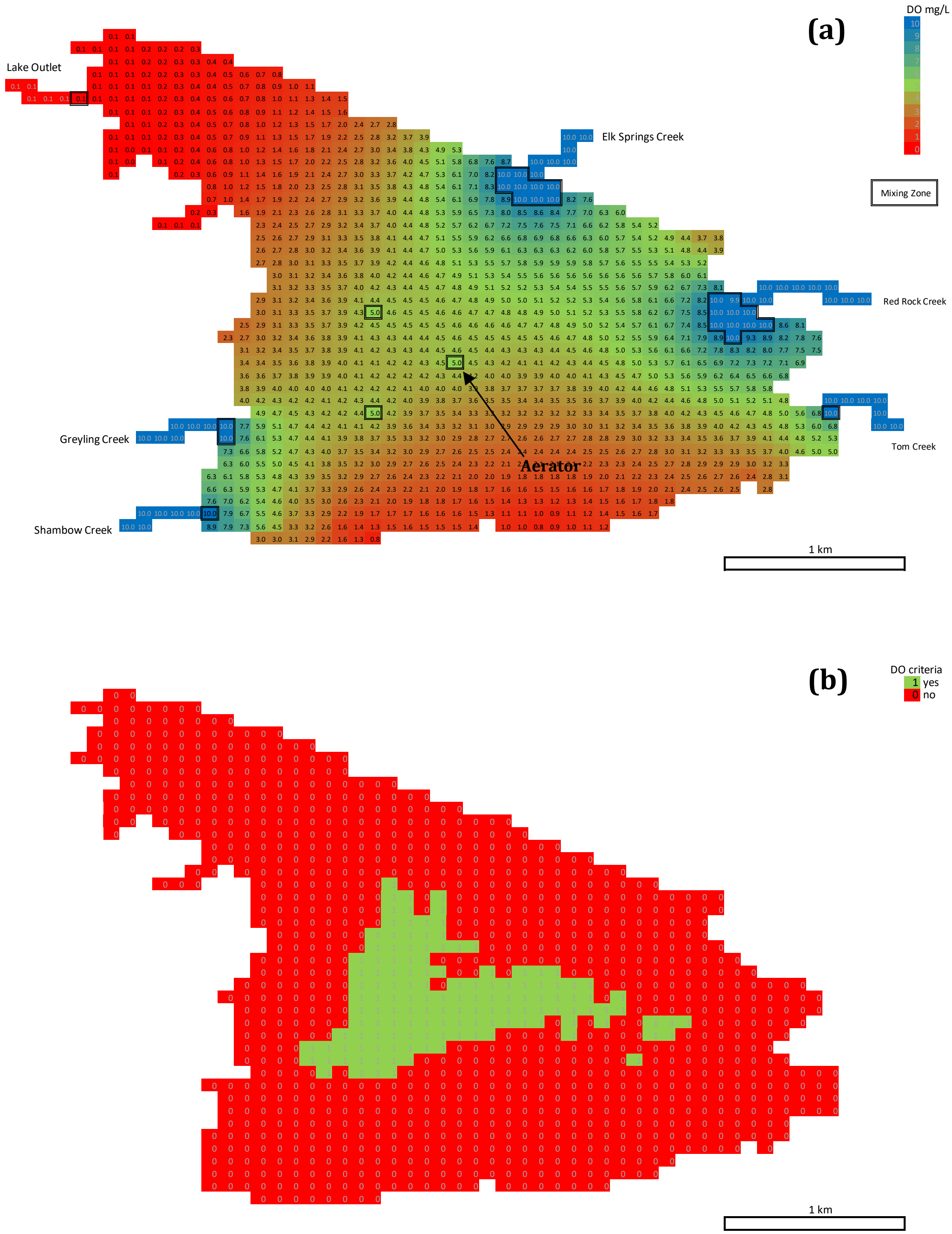


Figure 4-7
2-D Modeled Response of URRL to mechanical aeration
(a) Predicted oxygen concentrations. (b) Predicted winter habitat area.

4.6 Environmental Permitting

This section discusses the permitting requirements for the SolarBee® aeration option. Numerous regulatory policies, guidance documents, and agency personnel were consulted. Guidance derived from these sources is only as specific as the level of the designs allows and, therefore, is somewhat general at this stage of project development.

The aeration option comprises three aerators placed in the deepest part of URRL. Each aerator would be free floating and tethered to an anchor that rests on the bottom of the lake. The following assumptions have been made regarding this alternative:

- The SolarBees® would be delivered to the non-wilderness shoreline of URRL at the campground by standard motorized ground transport;
- The SolarBees® would be moved to each installation site in the lake by motorized, shallow draft watercraft (the units are too large and heavy to move by canoe or rowboat);
- Deployment by helicopter may also be an option, but would be very costly and would still result in temporary impacts to wilderness character;
- SolarBees® will be operated only during ice cover in winter when dissolved oxygen levels are low.

Approval of the SolarBee® alternative is expected to be challenging with respect to the Wilderness Act Minimum Requirements Analysis (MRA), given the potential long-term impacts to wilderness character; but relatively simple for other required permits. The estimated cost to obtain all permits except the Wilderness Act MRA is approximately $2,500, assuming no cultural or threatened and endangered species surveys are needed. Costs for the MRA are estimated to be approximately $25,000 to $35,000. Details on each of the anticipated permitting requirements are discussed below.

4.6.1 Section 404 Clean Water Act Permit

The SolarBee® alternative should qualify for Nationwide Permit (NWP) 18: Minor Discharges. NWP 18 limits discharges to less than 10 cubic yards. The anchors would be the only part of the installation considered to be discharge and the combined volume of those anchors is assumed to be considerably less than 10 cubic yards. No notification to the Corps would be required provided there are no wetland impacts, no impacts to threatened or endangered species, and no cultural resource concerns. Furthermore, no wetland delineation would be required.

4.6.2 Section 401 Clean Water Act Certification

Clean Water Act 401 Certification from Montana DEQ would be pre-authorized with NWP 18.

4.6.3 Montana Stream Protection Act – SPA 124 Permit

This alternative will not affect the bed or banks of any streams, so this permit is not likely to be required.

4.6.4 Temporary Turbidity (318) Authorization

Turbidity may occur as boats are launched to transport the SolarBees® and during deployment of the anchors, but this should not be subject to 318 Authorization. Consequently, authorization is likely be waived by FWP in consultation with DEQ during review of the Joint Permit Application.

4.6.5 Montana Pollutant Discharge Elimination System (MPDES) Individual Permit

MPDES does not apply to the aeration alternative.

4.6.6 Wilderness Act - Minimum Requirements Analysis

Assuming that activity to restore grayling populations is justifiable and necessary to meet minimum administration requirements for the wilderness area, the remainder of the MRA process will focus on finding the alternative that results in the least impact to wilderness character. The following positive attributes of the SolarBee® alternative should be promoted:

- The SolarBees® will be installed far enough from the shoreline that they will be difficult to see;
- The visibility of SolarBees® could be further reduced through camouflage or a lower profile design;
- SolarBees® are virtually silent to the human ear;
- SolarBees® run on renewable energy and do not contribute to climate change;
- SolarBee® installations can be retrieved permanently at any time to fully restore wilderness character to pre-project conditions.

Drawbacks to the SolarBee® alternative include:

- Mechanized equipment will be deployed in a wilderness area in perpetuity;
- Despite attempts to minimize visibility, SolarBees® will detract from the visual experience of wilderness;
- If the SolarBees® are deployed seasonally, that would result in increased use of motorized watercraft to deploy and retrieve the equipment.

Section 5

Alternative 2 – Tributary Diversion & Point of Inflow Modification

A second and simpler alternative to achieve the oxygen and depth criteria for URRL is moving oxygenated water from the shallow inlets to areas in the lake that meet the depth criterion. Potential sources for diversion include Red Rock Creek, Elk Springs Creek, Tom Creek, Shambow Creek, and Grayling Creek. Different strategies are required depending on which tributary or tributaries would be used[11].

5.1 Proposed Pipelines

A buried, gravity flow diversion pipeline is proposed for Alternative 2 since it would have no operation or maintenance requirements and is easy to engineer and construct. Two potential alignments are outlined to reflect different diversion sources, with the caveat that any of the tributaries could be used provided they have adequate flow and gradient. The conceptual design leverages existing pond systems within RRLNWR that are hydraulically connected and have operational/release potential. The proposed alignment options are as follows:

- Shambow Pond Diversion Pipeline (Option A) – This option collects water from Shambow Creek and Pond, including a nearby alluvial seep, and transfers the sum of those flows to the center of URRL. Winter flow available for this alternative is on the order of 1 ft^3/s (Table 1-1). Water from Grayling Creek and potentially even Odell Creek could possibly be used to supplement flow. Odell Creek is particularly interesting as it perhaps once connected with URRL through one of many historical channels on the valley floor (Appendix E). Prior USGS gaging indicates Odell Creek has appreciable flow and could add a stream of presumably well-oxygenated water that currently does not enter the lake.

- Widgeon Pond Diversion Pipeline (Option B) – This option uses the same approach as described above but instead diverts water from Widgeon Pond on the northeastern side of URRL. Flow out of Widgeon Pond and Picnic (Hackett) Springs Creek has not been measured, but originates from Culver Springs. We assume 2.5 ft^3/s is available for diversion, which allows us to test sensitivity of URRL to various inlet flow condition modifications. This option could be supplemented with flow from Elk Springs Creek.

A critical assumption for the pipeline alternative is that tributary flows are saturated with respect to atmospheric oxygen conditions. Surface water exposed to the atmosphere at an elevation of 6,615 ft (i.e., URRL elevation) should contain 10 to 11 mg/L of dissolved oxygen at winter temperatures of 0 to 4 °C (Chapra, 2008), which was used in our analysis. Calculated values

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[11] We have refrained from the diversion of flow from Red Rock Creek due the sensitivity and importance of this tributary for fish forage, spawning and rearing. Diversion from this source could potentially have adverse impacts on important aquatic species and/or riparian habitat.

should be field verified to make sure the assumption is not violated by localized conditions such as pond influences or low oxygen groundwater.

A paramount consideration in this alternative is the use of gravity flow and site topography. Gradients must be steep enough to overcome major friction losses in the pipeline, and to negate static head boundary conditions imposed by URRL. A proper representation of each is fundamental to sizing the pipeline correctly. For topography, we relied on the U.S. Geological Survey National Elevation Dataset (NED). The NED is a national $^{1}/_{3}$ arcsecond gridded elevation product (approximate 10 m resolution) referenced to the 1988 North American Vertical Datum (NAVD 88). Data were seamed with the FWP bathymetric survey of URRL to form a contiguous surface of the site. We assumed 5 feet of static head on the pipe at the center of the lake (elevation 6,615 ft).

Conceptual sizing of the pipelines for costing purposes were completed using the Extended Transport (EXTRAN) block of the Storm Water Management Model (SWMM). Dynamic flow was computed in each alignment using a simplified pipe network that had two straight pipe lengths and slope breaks that followed the general ground topography. While the approach is appropriate for conceptual design, it would need to be refined to move the design forward in the future.

Pipeline inlets are assumed to originate from within each pond and must be screened for fish passage, maintain enough entrance velocity to prevent freezing during the winter months, and use perforated laterals in URRL to diffuse the tributary water over an appropriate spatial region. Details about the diffuser design and plume behavior would need to be refined in design.

5.1.1 Shambow Pond Diversion Pipeline (Option A)

Shambow Pond is located southwest of URRL in RRLNWR (Figure 1-1) and serves as a suitable diversion point for the proposed pipeline. To increase flow, the alluvial fan spring that surfaces west of Shambow Pond (Figure 5-1) is proposed to be reconnected by blasting or excavation to increase flow to the pipeline entering URRL (note: this would likely cut off the spring's flow path to Grayling Creek). Another potential source is Odell Creek, which flows south across an alluvial fan from the Centennial mountains and westerly towards Lakeview. As noted by numerous meander belts over the valley floor (Figure 5-2), this stream could potentially contribute to URRL. Gaging data from USGS 06008000 Odell Cr ab Taft Ranch nr Lakeview MT indicate it has a drainage area 17.9 mi^2. During the years of 1997 and 1998 (wet years), the mean winter streamflow was 14 ft^3/s, which would be a substantial diversion source. FWP has also recently monitored Odell Creek at South Valley Road from 2016 to 2018, measuring similar values[12].

Option A is a pipeline that directly connects Shambow Pond with the center of URRL. Both a plan and profile drawing for this alternative are included in Appendix D. An engineered subsurface screened intake and gate structure is recommended at the pond outlet for storing pond water and conveying it along the lake through a high-density polyethylene (HDPE) pipeline. Gating will allow the pipeline to be isolated when not in use (e.g., late spring, summer, and early fall) so that flow can be returned to the natural channel. The end of the pipeline would contain two perforated laterals or, alternatively, diffuser ports for distribution of tributary water.

[12] In addition to potential water rights considerations, this option would require work on adjacent private property.

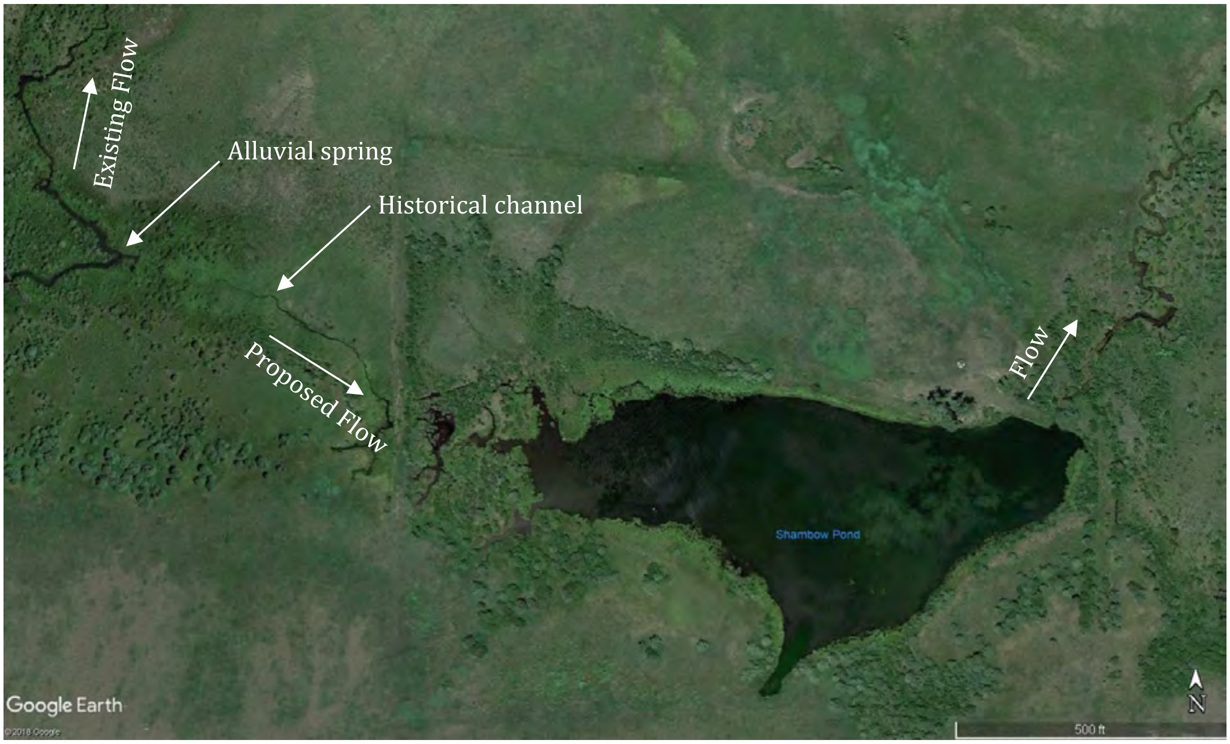

Figure 5-1
Shambow Pond location and alluvial seep flow routing

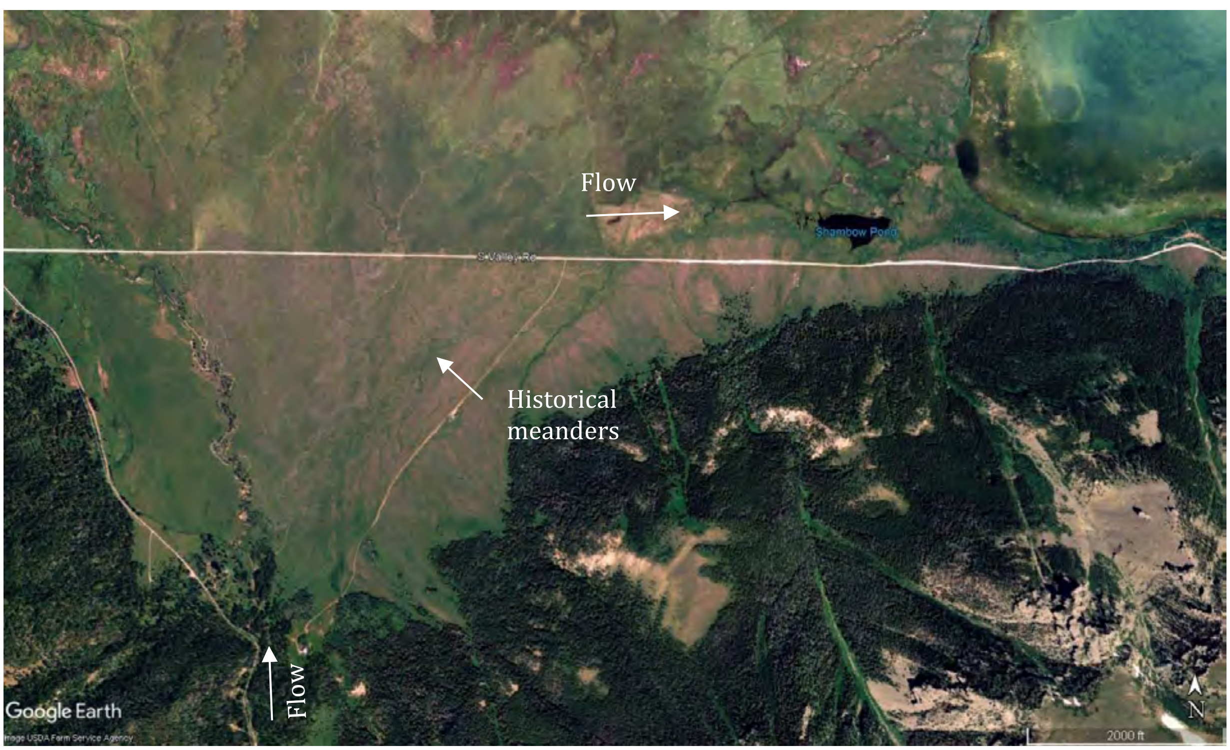

Figure 5-2
Aerial photograph of possible meander belts connecting Odell Creek to URRL

Based on an assumed target flow of 1 ft^3/s out of Shambow Pond (note: this could be increased if flow from Odell Creek could be obtained), SWMM modeling indicates the need for an 8-inch HDPE pipe from station 0+00 to 18+00 ft and then an 18-inch HDPE pipe from station 18+00 to 70+00 ft for a total pipeline length of approximately 7,000 ft.

Benefits of the Shambow Pond (Option A) tributary diversion and pipeline are as follows:

- Gravity flow and no operating expenses;
- Easy to design and implement;
- Potential flow and oxygen increases from a connection with Odell Creek, which would add a new tributary source currently not entering URRL.

Drawbacks of the pipeline alignment are as follows:

- Temporary disturbances to wetlands associated with construction;
- Installation of permanent, although buried, infrastructure within a wilderness setting;
- Fish and wildlife consequences associated with reductions in surface water flows;
- Potential fouling of the pipeline and diffuser system by algae, sediment, or debris;
- Removal of a point source inflow on either side of URRL will alter the spatial distribution of oxygen concentration and will likely result in deoxygenation of the west side of URRL.

It is important to recognize that we did not address water rights in any of the options discussed above, which will need to be investigated by the agencies should any of these options be carried forward into design and implementation.

5.1.2 Widgeon Pond Diversion Pipeline (Option B)

Widgeon pond is northeast of URRL and presents a different diversion opportunity from a second source (Figure 5-3). The pipeline from Widgeon Pond was evaluated using the same procedures discussed previously and differs from the previous option in pipeline length and topographic constraints. Shallow gradients exist throughout much of the proposed alignment and would require larger pipe sizes along the entire length to convey the assumed 2.5 ft^3/s target flow to the center of the lake.

Based on site grades, a 12-inch HDPE pipe will be required from station 0+00 to 23+00 ft. The change in grade in the valley and along the lake bottom will require an 18-inch HDPE pipe from station 23+00 to 209+00 ft (18,600 ft) for a total pipeline length of approximately 20,900 ft.

Figure 5-3
Widgeon Pond location

Benefits of the tributary diversion and pipeline from Widgeon Pond are as follows:

- Gravity flow and no operating expenses;
- Easy to design and implement.

Drawbacks of the pipeline alignment are as follows:

- High costs. This alignment requires a significant capital investment relative to Option A;
- Installation of permanent, although buried, infrastructure within a wilderness setting;
- Fish and wildlife consequences associated with reductions in surface water flows;
- Potential fouling of the pipeline and diffuser system by algae, sediment, or debris;
- Removal of a point source inflow on this side of URRL will alter the spatial distribution of oxygen concentration and will likely result in lower oxygen conditions on the east side of URRL.

5.2 Costing and Preferred Pipeline Option

Two separate options and sources for tributary diversion have been considered. Costs of the proposed projects are a function of the pipeline length, diameter and burial depth. An OPCC commensurate to a Level 5 accuracy for each of the pipelines is shown in Table 5-1. Costs include pipeline purchase price, pipe bedding, and installation using traditional construction approaches. The largest expense is the cost of pipe and the equipment/labor for installation. As with other alternatives, motorized access is restricted and is expected to be a consideration in implementation. Wilderness and permitting limitations are discussed at the end of this section.

Table 5-1 Estimated installation costs of the proposed tributary diversion pipelines

Aeration Type	Estimated Option Cost ($) [a]
Shambow Pond Diversion Pipeline (Option A)	$260,262
Widgeon Pond Diversion Pipeline (Option B)	$956,984

[a] including 10% contingency
Shambow Pond Diversion does not include reconnecting the alluvial seep

The estimate above is an OPCC that includes material, labor and equipment. It does not cover probable total costs such as design, project administration, and permitting. Site access and wilderness impacts, permitting, technology performance evaluation and initial pilot testing, and operation and maintenance are not included either.

5.3 Modeled Response and Other Considerations

Model results for the conceptual design of the Shambow pipeline alternative in URRL are shown in Figure 5-4. Predicted habitat is estimated to be greater than 25 ha and is generally focused around the diffuser exit locations. We prescribed a concentration at the diffuser discharge point in the model that incorporates estimates of sediment oxygen demand and outward diffusion, with a hydraulic residence time of about four days (due to the flow rate of 0.5 ft^3/s in each diffuser), so the influent grid cell approximates a concentration of 5 mg/L.

In review of the results, modeled responses results should again be used with caution since predicted concentrations are very near the 4.0 mg/L habitat criterion threshold. Likewise, associated flow and oxygen concentrations of the diversion sources (i.e., model boundary conditions) have not been measured. The project team recommends at a minimum one year of winter monitoring to establish a basis for flow conditions and associated DO concentrations before moving forward with this alternative. Moreover, the availability of water at each location, water rights considerations, and wilderness area requirements should be addressed before any pipeline alternative can be pursued.

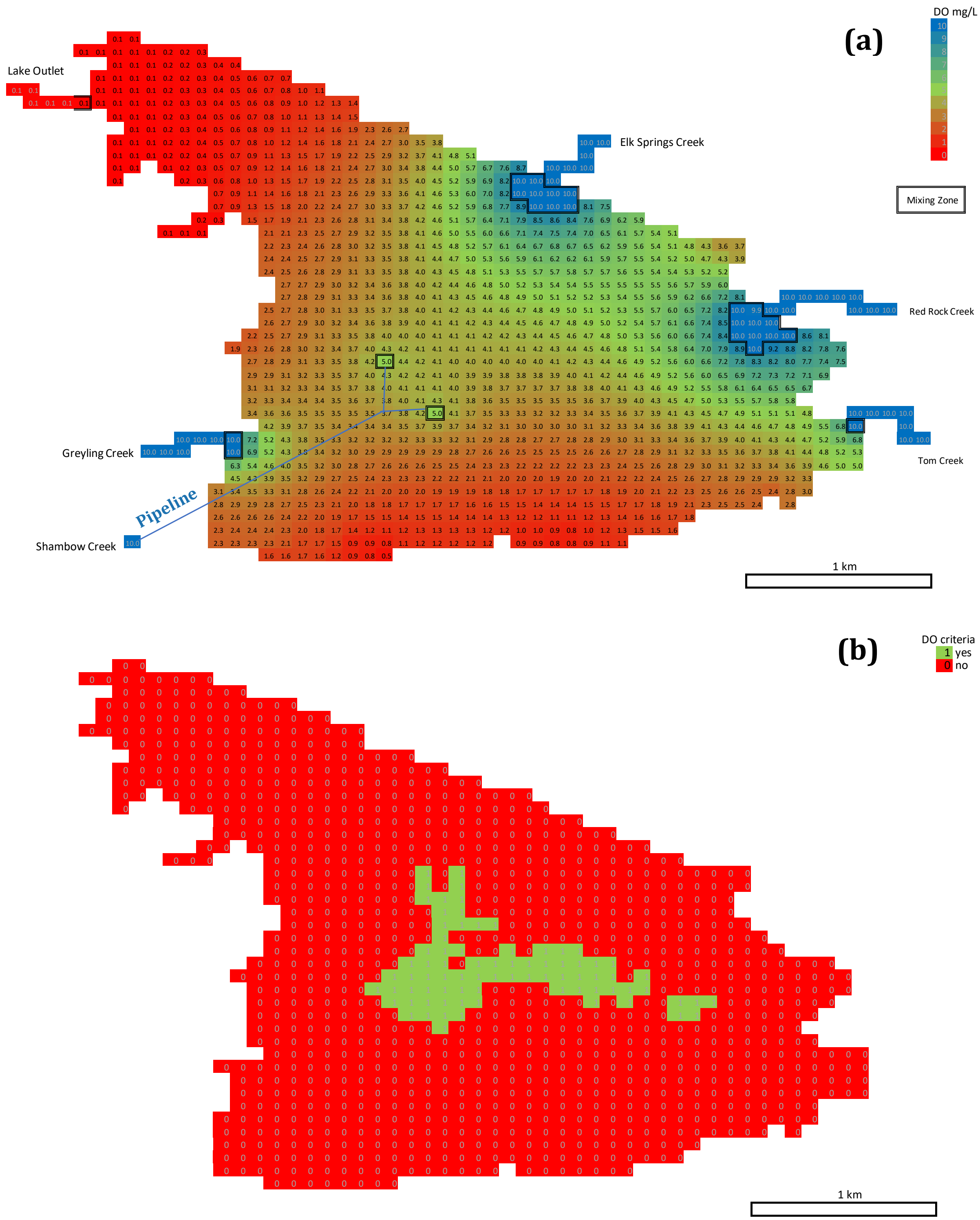

Figure 5-4
2-D Modeled Response of URRL to the pipeline option
(a) Predicted oxygen concentrations. (b) Predicted winter habitat area.

5.4 Permitting

This section discusses the general permitting requirements and strategy for the tributary diversion alternative. Numerous regulatory policies, guidance documents, and agency personnel were consulted. Guidance derived from these sources is only as specific as the level of the designs allows and, therefore, is somewhat general at this stage of the project development.

The tributary diversion alternative has two options, Option A which would divert the outflow from Shambow Pond into the deepest portion of the URRL, and Option B, which would do the same, but for Widgeon Pond. Only Option A is considered here, as Option B is very costly and expected to result in much greater environmental impacts. The following assumptions have been made regarding installation of the pipeline:

- The 2,700-foot submerged section of pipe within URRL may be installed on the lake bed or buried;
- If buried, the temporary disturbance to wetlands for the submerged portion of pipeline is expected to be about 10 feet (3 feet for the pipe trench and 7 feet for spoils windrows), yielding a disturbance of 0.68 acres. If installed on the lake bed, the disturbance will permanently impact 0.09 acres of wetland;
- The remaining 1,800 feet of the pipe will be installed in a pipe trench approximately 2 feet wide and 2 to 3 feet deep;
- Disturbance to wetlands for the overland portion of the pipeline is expected to be similar yielding a disturbance footprint of approximately 0.41 acres;
- The entire length of the pipeline outside of the lake will pass through jurisdictional wetlands;

Installation of the pipeline is expected to involve motorized heavy equipment to excavate and backfill the pipe trench as there is not reasonable alternative means for installation. In addition, motorized watercraft will be needed to aid in installing the submerged portion of the pipeline. If the submerged portion is also buried, a floating barge may be needed to support heavy equipment.

Approval of the tributary diversion alternative is expected to be moderately challenging for all permits. The estimated cost to obtain all permits except the Wilderness Act MRA is approximately $35,000. Five years of post-project monitoring will cost around $25,000. Costs for the MRA are estimated to be approximately $25,000 to $35,000.

5.4.1 Section 404 Clean Water Act Permit

This alternative would likely be permitted using Nationwide Permit 12: Utility Line Activities. A pre-construction notification will be required because the pipeline exceeds 500 feet. Wetland impacts may be considered temporary and self-mitigating by the U.S. Army Corps of Engineers if the following guidance is followed:

- The amount of wetland loss does not exceed 0.10 acres;
- Topsoil and vegetation are salvaged and reinstalled following installation;
- Other excavated material is stockpiled separately in a temporary windrow along the pipeline alignment;
- Any excess material is hauled and reclaimed in a suitable upland area;
- The ground surface is restored to pre-construction elevations and reclaimed with native seed;
- Pipe bedding material is minimized and seepage collars or clay plugs are installed periodically to reduce transmission of groundwater along the pipeline.

A wetland delineation will be required and monitoring of the site may also be requested by the Corps for 5 years or until the reestablishment of wetlands can be documented.

5.4.2 Section 401 Clean Water Act Certification

An individual 401 certification will be required. It is recommended that special measures such as sediment curtains or other engineering controls be incorporated into designs to reduce sedimentation in URRL. Certification fees are based on 1% of construction costs with a minimum fee of $400 and maximum of $20,000. It is expected the fee for this alternative would be maximum $20,000. However, DEQ may waive this fee if requested by FWP.

5.4.3 Montana Stream Protection Act – SPA 124 Permit

This alternative as currently proposed will affect the outflow stream to Shambow Pond at several locations. However, the pipeline alignment could be shifted to the east 150 feet or west about 300 feet to avoid stream impacts. It is assumed the alignment will be adjusted to avoid stream impacts, thereby making the SPA 124 Permit unnecessary.

5.4.4 Temporary Turbidity (318) Authorization

Turbidity will occur if the submerged portion of the pipeline is buried beneath the lake bed. Consequently, 318 authorization is likely be required. This authorization is straightforward and relatively easy to acquire. There is a $250 application fee. DEQ may also waive this fee if requested by FWP.

5.4.5 Montana Pollutant Discharge Elimination System (MPDES) Individual Permit

This permit will not apply to the tributary diversion alternative, provided no water will be discharged.

5.4.6 Wilderness Act - Minimum Requirements Analysis

Assuming again that some activity to restore grayling populations is justifiable and necessary to meet minimum administration requirements for the wilderness area, the remainder of the MRA process will focus on finding the alternative that results in the least impact to wilderness character. The following attributes of the tributary diversion alternative should be promoted approval through the MRA analysis:

- The pipeline system is passive, requiring no mechanical equipment to operate;
- The gravity pipeline will not contribute to greenhouse gases and climate change;
- If buried and properly reclaimed, the pipeline will not be visible;
- Disruptions to wilderness character will occur only during construction;
- Maintenance requirements are expected to be very low.

Drawbacks to the tributary diversion alternative include:

- Mechanized equipment will be required to install the pipeline;
- If installed on the lake bed, the submerged portion of the pipeline will be visible through the water;
- Though largely invisible, the installation will permanently alter the wilderness.

Section 6

Alternative 3 – Dredging or Volume Enhancement

The third proposed alternative to improve winter grayling habitat in URRL is to construct habitat near the tributary inlets, where DO concentrations already exceed the management criterion, but depths do not meet the 1m criterion. Two potential variations of this alternative have been considered:

- Dredging or excavation at the tributary mouths to achieve the overwinter depth criterion through direct sediment removal;
- Volume increases to the lake through changes in the outlet configuration such the overall depth of the lake is deepened.

Each option is discussed subsequently. It is important to note that neither adds oxygen to the lake during winter months, but rather creates depth habitat in locations that are well oxygenated. Dredging could include localized actions such as deepening of inlets via blasting.

6.1 Dredging at Tributary Inlets

The dredging alternative removes sediments near tributary mouths with a shallow draft floating dredge to meet the winter habitat depth requirement (>1 m). Dredging would be a large project covering 62 acres (25 hectares) with removal of up to a meter of sediment (plus sediment storage). The proposed area for deepening is centered between the two primary inflows, i.e., Red Rock Creek and Elk Springs Creek, for conceptual purposes to provide winter connectivity between the two inlets. The mouths of these tributaries have been identified as locations where fish seek refuge during low oxygen winter conditions in URRL. Operations could be shifted anywhere on the northeastern shoreline provided oxygenated conditions have been observed previously there. If the Elk Springs Creek delta is a concern as noted in Section 2.3.4.3, this area could be included in the dredging scope of work.

Access to the site for implementing hydraulic dredging would be from the boat launch at the southern campground, outside of the wilderness area. However, the launch is primitive and may have to be reinforced or widened to deploy the dredge. Mechanical dredging at this site is not advised as it would be more complex, requiring staging and operation of construction equipment in the wilderness area, as well as development of temporary construction access, haul roads, staging areas, and dredged material drying pads. These are all difficult from geotechnical perspective to construct due to groundwater upwelling in the valley, assumed substrate characteristics, and permitting and regulatory requirements.

The proposed area of dredging is shown in Appendix D. Cut and fill calculations were completed in AutoCAD Civil 3D using the bathymetric data from Montana Fish, Wildlife & Parks[13] to a depth of 1.25 m (4.1 ft) during ice-covered conditions (finished lake bed elevation 6609.25 ft), with

[13] We smoothed the original raw point bathymetric data for this calculation to better remove ship tracks from the original data.

over-excavation of 0.25 m (0.8 ft) to account for sedimentation. The following assumptions were made about the dredged area:

- 25 hectares of habitat were created with ice-cover depth >1 m (0.5 m ice cover assumed);
- 10:1 side slope on the shoreline side;
- 50:1 slope on the southwest facing side of the dredge cut;
- A proposed completion elevation of 6616 ft, one foot above the normal high-water level.

Based on these assumptions, the total dredged volume would be 313,500 CY (expansion volume not included). The volume is considerable and would require a well-thought out material disposal plan for the dredged material.

6.2 Material Disposal

6.2.2 Artificial Island Creation

The reuse of dredged material for environmental restoration purposes is an effective disposal option and has been used to build islands, seed islands, or provide bank protection (Millhollin, 2006). The most attractive option for this alternative is construction of an artificial island to house the dredge cuttings, scaled at a size equivalent to the cut volume noted previously. This disposal technique eliminates the need for haul (and potentially drying) of dredged material and has been effectively used by the U.S. Army Corps of Engineers, therefore is probably permittable under Section 404 of the Clean Water Act. An analog for the artificial island construction can be found by examining Lower Red Rock Lake (Figure 6-1) where numerous dished-out island features exist that presumably were shaped by prevailing winds.

An artificial island in the lake could benefit waterfowl and other avian species but may increase fish predation by piscivorous birds. According to the U.S. Army Corps of Engineers (2015), islands must be permanently emergent at high-water levels and should be high enough to prevent flooding of the areas that could be used by waterfowl for nesting. Steep slopes, such as those found on dikes, should be avoided and slopes less than 1 m (3 ft) rise per 30 m (100 ft) of run are recommended (U.S. Army Corps of Engineers, 1986). We find it difficult to achieve these recommendations based on material compensation and volume.

Stabilization of the island is important. Nearshore placement is becoming an increasingly utilized method for beneficial use of dredged material and the use of geotextile tubes to form the perimeter dike for the dredged material containment facility has proven to be both technically and economically feasible. The materials above would need to be overlain by an engineered cover that is protective of wave erosion. Our initial proposal would be the retention of dredge cuttings by large geotextile sand-filled bags/tubes similar to the Big Bag® cofferdam concept described in Section 2 and with a vegetated cover.

To prevent impacts to other locations in the lake, floating silt/turbidity curtains (effective only in certain parts of the United States, under certain soil conditions) or temporary dikes may be required during placement activities. The generation of turbidity by hydraulic dredge type has already been characterized by the U.S. Army Corps of Engineers (2015) and impacts are expected.

It is assumed that tributary inflow sedimentation rates are low such that the dredged area will not be covered by incoming sediment, but over-excavation is recommended nonetheless.

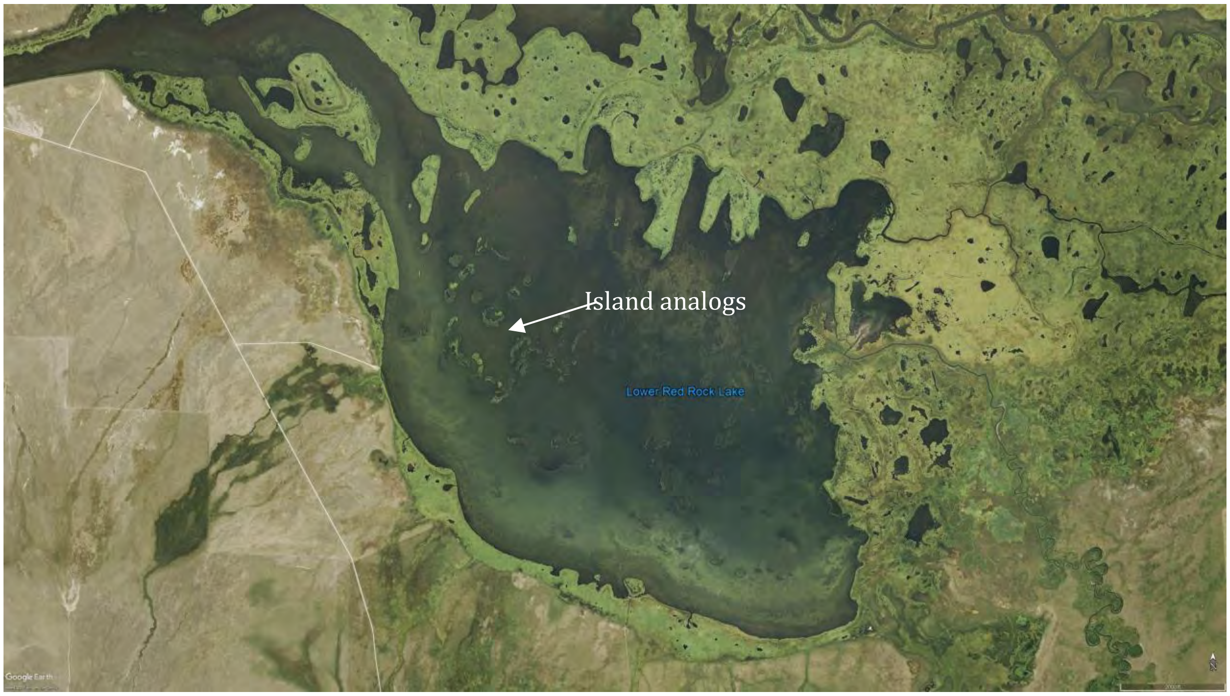

Figure 6-1
Artificial island analog from Lower Red Rock lake

It is important to note that dredging may only be an interim solution. Depending on sediment resuspension in the lake, dredging may be required on a regular basis. The movement of lake bed sediment due to wind and wave action could fill deepened areas and we suggest that sediment traps be placed in the lake for at least one summer to assess sedimentation rates, since the potential for re-inundation of sediment in the dredged area is a concern.

Benefits of dredging are as follows:

- Habitat creation at tributary inflows and locations of highest oxygen concentration;
- Beneficial habitat may be created through use of an artificial island to store the dredge cuttings.

Drawbacks of the dredging are:

- Very high costs;
- Temporary noise and environmental impacts (e.g., turbidity);
- Potential filling of dredged areas over time. [14]

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[14] Muma et al. (2012) indicate sediment accumulation in Lower Lake of about 1 foot of sediment per 1,000 years based on carbon dating of organic material.

The feasibility of new island construction depends on Federal and State agency permitting, along with input from the private sector. These concerns vary considerably among the regions of the country and may represent an impediment to this alternative. However, it has been proven that construction of new islands for birds and other forms of wildlife is feasible.

6.2 Volume Enhancement

Volume enhancement, by means of lake outlet modifications to increase the normal water level, was also a high-ranking alternative. Increasing the normal water level will increase the lake volume and initial oxygen reserve at the time of ice cover but does not directly contribute to oxygenation since well-oxygenated water remains at the shallow inlet locations. An increase in the normal water surface elevation reduces the sediment area to lake volume ratio (Mathias & Barica, 1980), a noted factor in the winter deoxygenation rate (Figure 6-2). Based on an existing sediment area to lake volume ratio of 0.93 in URRL, a three-foot increase in water level would roughly halve the volumetric winter oxygen depletion rate. Certainly this would slow the oxygen demand on the overall pool and thereby benefit URRL.

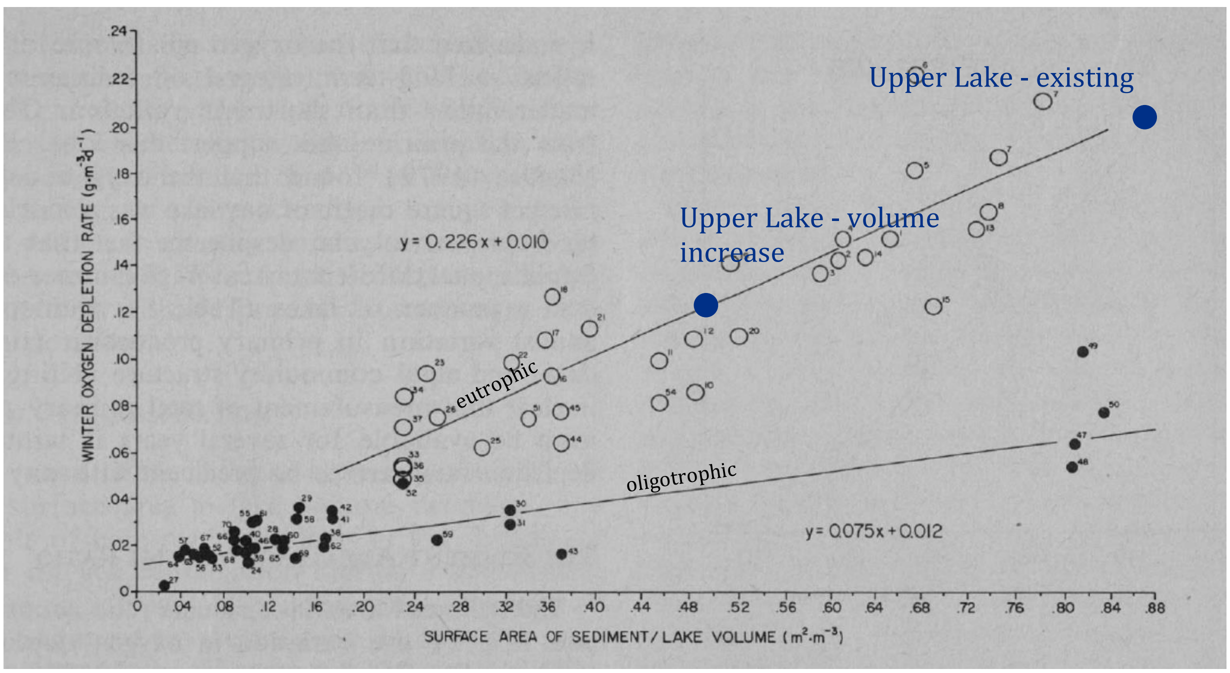

Figure 6-2
Winter oxygen depletion sediment to volume relationship (Mathias & Barica, 1980)

Lake outlet modifications may create jurisdictional dam issues. Due to the flat topography a contiguous berm will be required around URRL. Assuming a trapezoidal cross-sectional geometry with a top width of 10 ft, 3:1 side slope, and 3 ft increase in water surface elevation, the net fill requirement for such a project would be over 170,000 cubic yards. Much of this fill would have to be placed in wetlands, which would create a significant permitting obstacle. Since borrow sources are a far distance away, the most useful source would be the dredge cuttings noted in the previous section such that volume enhancement should only be undertaken concomitantly with dredging. The combination of these factors make volume enhancement an unlikely alternative. Finally, upstream spawning segments of all incoming tributaries will become inundated from this

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alternative while reaches further upstream will be transformed from free-flowing to slack-water habitat due to the increase in lake surface elevation. Additional topographic data is necessary to reliably assess this alternative.

6.3 Cost Estimate and Construction

SRS Crisafulli, Inc., a Montana dredging contractor, provided a quote for a Rotomite SD-110 hydraulic dredge, which has an 18-inch draft and versatile maneuverability. Assuming a 750-foot discharge distance, and 20 feet of elevation change, 9,000 to 11,000 CY of solid material can be moved per month at cost of $2.75-$3.00 per CY. Based on the volume estimates above, the overall duration of dredging and construction would be about 29 months with a single unit (i.e., multiple seasons). The costs above reflect machine costs only, and do not include additional piping, labor, permitting, or dewatering costs. A separate estimate was obtained by a mechanical dredging contractor (drag line) but we have not included it due to previously noted issues. Overall estimates for the dredging and artificial island construction are shown in Table 6-1.

Table 6-1 Estimated costs of dredging or volume enhancement

Alternative	Estimated Option Cost ($)
Dredging & Island Creation	$2,324,375
Volume Enhancement	Na

na = no estimate made. We have not estimated costs for volume enhancement as topographic information is insufficient and placement of large quantities of fill in adjacent wetlands make the alternative improbable.

6.4 Potential Impacts

Dredging will cause significant site disturbance and ecological/environmental impacts that should not go unmentioned. Included is accidental capture or mortality of migratory birds and temporarily water quality impacts. Effects on sensitive aquatic species can be avoided by selecting a dredge type that reduces or avoids accidental capture. Less-mobile organisms can be temporarily relocated during dredging. Impacts to organisms and aquatic vegetation that live in or on the dredged sediments are unavoidable. While adult fish generally avoid areas where dredging is taking place, dredging operations should be designed to avoid certain windows of time when critical life history functions are underway such as spawning or nesting (for birds). Temporary water quality impacts can be lessened by using equipment that includes turbidity barriers like silt curtains. Construction staging will require temporary wilderness access and may also create disturbed lands, requiring restoration to a pre-construction condition. Disturbed land can result in weed infestations that require 3 to 5 years of monitoring and management to control.

If dredging were to be selected as the preferred alternative, we recommend implementing the following monitoring programs to address water quality impacts and noise or disturbance levels during construction: continuous monitoring of turbidity so that >50 NTU monthly average is not exceed, ensuring noise levels do not exceed 75 dB at any given time, and then a robust vegetation recovery monitoring program.

Finally, it is important to note that unpublished results from Mike Davis (Figure 6-3) indicate fish congregate at the tributary inlets during winter months, in particular at Elk Springs Creek. In undertaking dredging, it should be ensured that activities do not have a negative influence on why fish are drawn to these locations. More should also be done to understand why these locations are preferentially targeted by fish, noting that depths <1 may serve as suitable refugia when no other alternative exists. By recognizing and exploiting existing grayling habitat preferences, small improvement projects may be undertaken in critical habitat locations.

Figure 6-3
Results of the Mike Davis fish survey for URRL (unpublished), winter 2013–2015

6.5 Modeled Response and Other Considerations

Model results for the conceptual design of the dredging alternative are shown in Figure 6-4. While no change in the spatial distribution of oxygen occurs, predicted habitat is estimated to be 25 ha exactly, with the additional habitat residing in the dredged area between Red Rock Creek and Elk Springs Creek. Predictions for the volume enhancement project are not shown because of implementation concerns but do provide considerable improvement in DO concentration. Should a volume enhancement project be undertaken, more robust dissolved oxygen modeling procedures should be undertaken to provide definitive conclusions regarding this alternative.

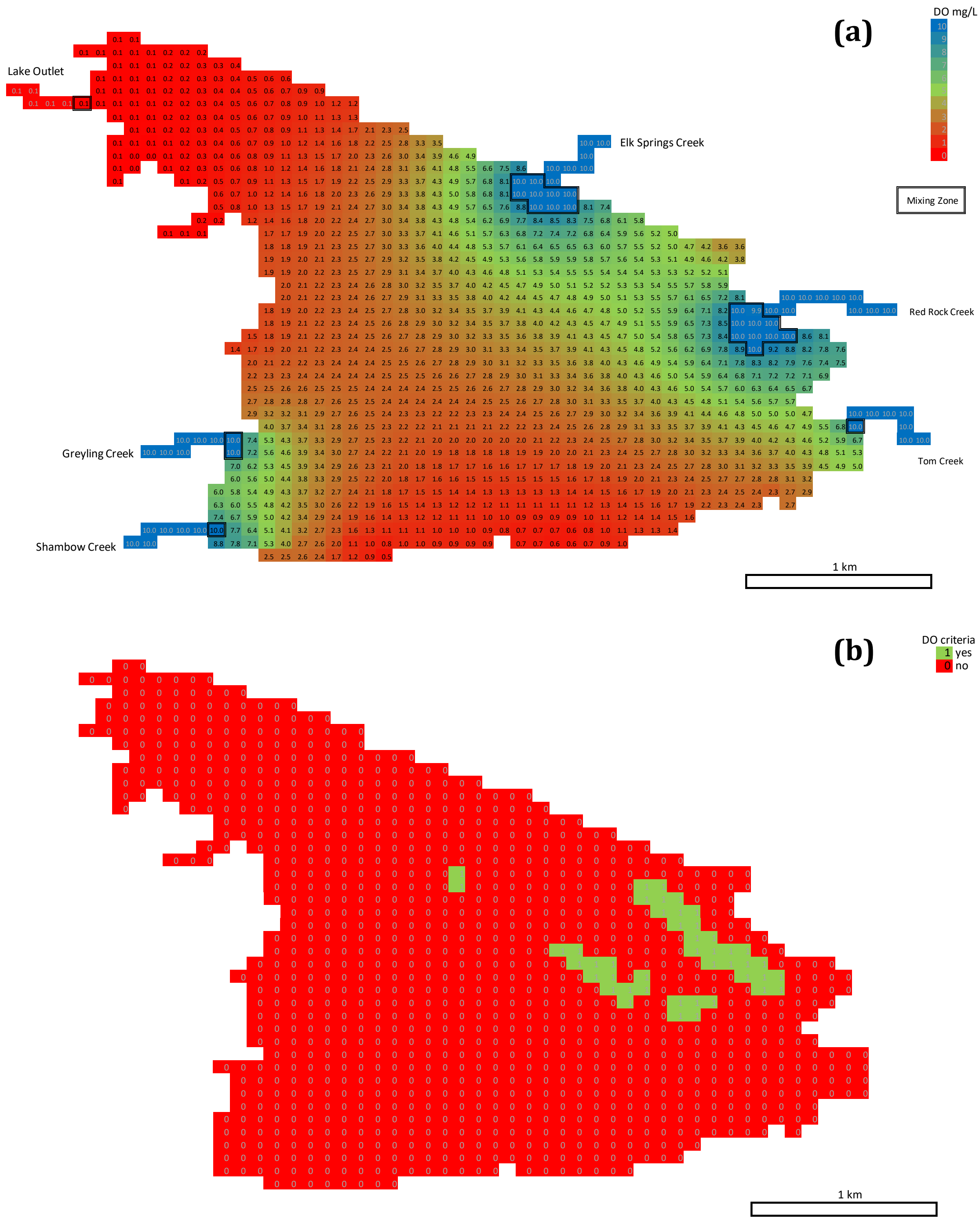

Figure 6-4
2-D Modeled Response of URRL to the dredging alternative
(a) Predicted oxygen concentrations. (b) Predicted winter habitat area.

6.6 Permitting

This section discusses the general permitting requirements and strategy for the dredging alternative. Numerous regulatory policies, guidance documents, and agency personnel were consulted. Guidance derived from these sources is only as specific as the level of the designs allows and, therefore, is somewhat general at this stage of project development.

The dredging alternative contemplates the creation of a deeper area on the northeast side of URRL in the vicinity of Elk Springs Creek and Red Rock Creek that is roughly 62 acres in size and 5.75 feet deep. The dredged material would be used to create a low profile, island in the lake that is roughly 37-acres in size. The following assumptions have been made regarding the dredging alternative:

- A motorized suction dredge will be used for construction;
- Deep water habitat created by dredging will be permanent and won't fill in due to resuspension of lakebed sediments;
- Dredge spoils will be pumped to an enclosure formed by sand-filled geotextile tubes;
- An engineered cover (e.g. vegetated rock blanket) will be placed over the geotubes and shoreline of the created island to protect it from wave erosion;
- The shape and elevation of the island will be modeled/constructed after existing islands present in Lower Red Rock Lake;
- The island will be revegetated with native plants to provide habitat for waterfowl and other wildlife.

Approval of the dredging alternative is expected to be virtually impossible for the MRA. Approval of other permits is expected to range from moderately to very challenging. The estimated cost to complete the Wilderness Act MRA is approximately $25,000 to $35,000. Costs for all other permits is estimated to be $45,000, plus an additional $25,000 for 5-years of post-project monitoring.

6.6.1 Section 404 Clean Water Act Permit

Due to the size and the magnitude of the proposed dredging alternative, a representative from the Corps of Engineers Montana office was contacted. They were inclined to believe that an individual permit is required. However, they also indicated it may be possible to obtain a Nationwide Permit 27: Aquatic Habitat Restoration, Establishment, and Enhancement Activities. The decision regarding eligibility for NWP 27 will be made at the discretion of the Corps of Engineers. It will be important to begin consultation with the Corps of Engineers early in the project to negotiate in favor of using NWP 27. Negotiations should stress that:

- The project purpose is to enhance fish habitat for an imperiled population of arctic grayling;

- The project will establish 32 acres emergent wetland island habitat, resulting in a net increase in aquatic resources;
- The project design is based on an ecological reference, such as islands and deep-water habitat that occur in Lower Red Rock Lake or other nearby natural waterbodies.

A wetland delineation would likely not be required for either permit because the work will occur in the lake itself and would not impact wetlands. However, monitoring of wetland establishment on the island for up to 5 years may requested by the Corps.

6.6.2 Section 401 Clean Water Act Certification

If use of NWP 27 is authorized, the 401 Certification may be automatic from the DEQ. However, due to the extent of the proposed dredging, DEQ may still require an individual certification. In that case, certification fees would be based on 1% of construction costs with a minimum fee of $400 and maximum of $20,000. It is expected the fee for this alternative would be maximum $20,000. However, DEQ may waive this fee if requested by FWP.

6.6.3 Montana Stream Protection Act – SPA 124 Permit

This alternative will not affect the bed or banks of any streams, so this permit is not likely to be required.

6.6.4 Temporary Turbidity (318) Authorization

Turbidity will occur during dredging and fill operations within URRL. Consequently, 318 authorization is likely be required. This authorization is straightforward and relatively easy to acquire. There is a $250 application fee.

6.6.5 Montana Pollutant Discharge Elimination System (MPDES) Individual Permit

An individual permit for suction dredging from the DEQ will be required. Specific measures to minimize turbidity and sedimentation of State Waters are likely to be required in the permit application. The cost for this permit is expected to range from $12,500 to $16,000.

6.6.6 Wilderness Act - Minimum Requirements Analysis

Assuming once again that some activity to restore grayling populations is justifiable and necessary to meet minimum administration requirements for the wilderness area, the remainder of the MRA process will focus on finding the alternative that results in the least impact to wilderness character. The following attributes of the dredging alternative should promote approval through the MRA analysis:

- Deep water habitat will partially restore historic bathymetry to URRL;
- The nesting island, if properly designed and constructed, will resemble any other natural island that might occur within the refuge;

- If lakebed sediments are relatively stable, this alternative will produce long-term habitat improvements with little or no maintenance requirements;
- The created island will provide 32 acres of nesting habitat for waterfowl, including trumpeter swans.

Drawbacks to the dredging alternative include:

- Mechanized equipment will be required;
- Motorized boat traffic to ferry operators and supplies to the dredge will disrupt wilderness character on a daily basis during construction;
- At standard dredging rates, the project may take up to five years to complete using a single dredge;
- The created spoils island will be constructed in part with synthetic geotextile materials that will remain in the lake environment forever;
- The engineered cover over the margins of the spoils island will create a hardened, rocky shoreline uncharacteristic of URRL.
- Spoils placement may result in water quality degradation for the duration of construction.

Section 7

Pilot Study Recommendations

This section contains pilot study recommendations for improving overwinter conditions in URRL considering both the engineering evaluations and permitting requirements discussed in previous sections. If possible, activities should begin in the summer of 2019 and continue through the winter and spring of 2020. This will allow performance monitoring of proposed technologies and will provide time to fill data gaps for other alternatives. The phasing is discussed subsequently, followed by further details about the proposed activities.

7.1 Phased Approach

CDM Smith is recommending a phased approach for piloting of certain technologies in URRL during fiscal year (FY) 2020 while at the same time collecting data to inform the other alternatives. The proposed approach is shown in Figure 7-1 and is expounded upon in subsequent sections. Installation of SolarBee® mixers from Medora Corporation is our preferred alternative in terms of initial costs, operation and maintenance requirements, and minimizing wilderness site impacts. It is believed this technology should be piloted first as alternatives such as tributary diversion or dredging require at least one year of data collection to fill data gaps. Moreover, operation of one alternative at a time will prevent confounding performance monitoring results.

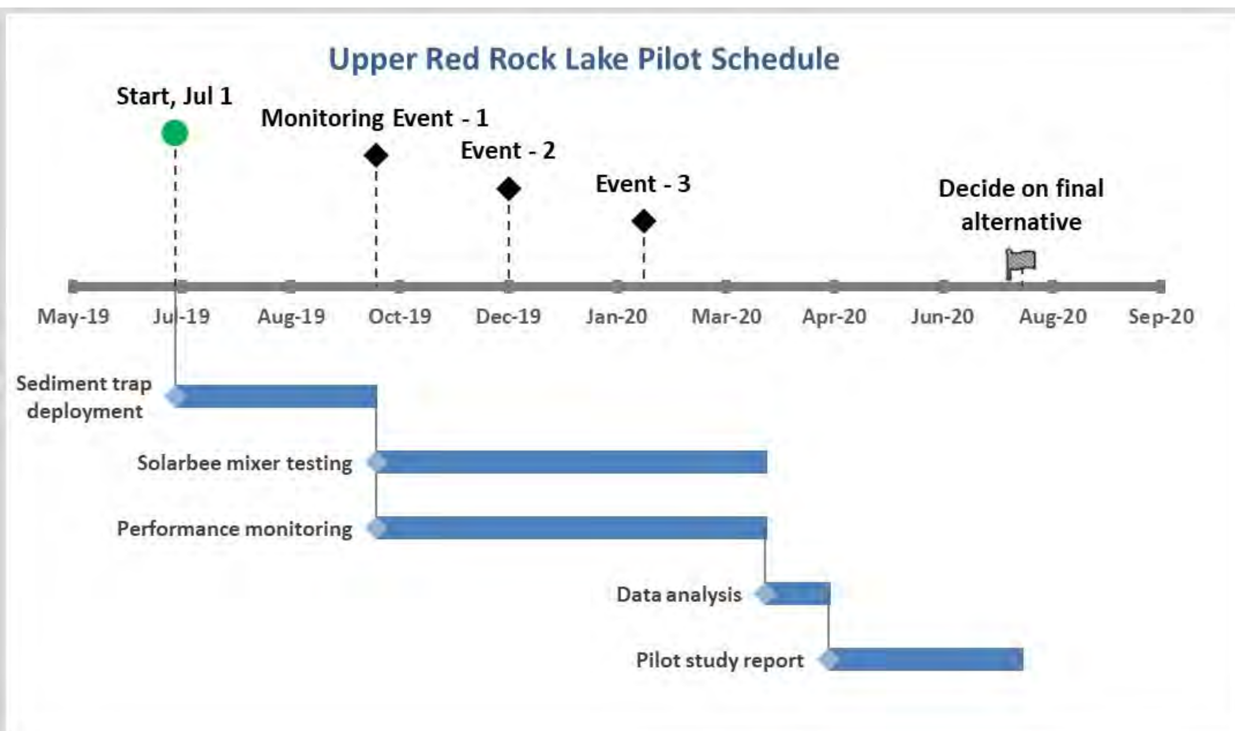

Figure 7-1
Proposed phasing of pilot studies for URRL

7.2 Solarbee Mixer Pilot Testing

SolarBee® mixers have a modular design and expandable configuration that is ideal for pilot testing. Moreover, they require limited up-front planning and avoid large upfront capital expenditures (unlike the other options evaluated). Units can be rented and installed by Medora at a cost of approximately $13,214 per six-months, and the rental cost can be recovered by FWP or USFWS should they purchase the unit at the end of the pilot period. An added benefit of the Medora rental program is that a full winter of performance monitoring data can be acquired prior to making a purchasing decision, thus making a fully informed decision about their implementation effectiveness.

Provided the grayling population in URRL is not at immediate risk, we recommend placing one SolarBee® unit in the initial year of operation at the midpoint of the lake and then carefully monitoring oxygen concentrations in the surrounding area to assess performance. Winter monitoring should include DO concentrations, turbidity, polynya size, fish movements, and power management. Supplementary aeration units can be installed in subsequent years once it is demonstrated that the technology performs as advertised in the Centennial Valley. A robust monitoring program would include the following:

- Characterization of spatial gradients of DO and turbidity in proximity to the aerator/mixer. We suggest developing a sampling program that uses satellite enabled datasondes spaced radially at approximately 100 to 250 meters horizontally (Figure 7-2). The real-time component is extremely important due to the possibility for the units to reduce the thickness of the diffusive boundary layer and increase SOD.
- Estimation of the size of the polynya (shape, diameter, etc.) through unmanned aerial vehicle (UAV) photography at select dates during the winter months;
- Evaluation of fish movements in the oxygenated area through traditional fish survey techniques or unattended underwater camera attached to the SolarBee® structure;
- Installation of a portable weather station on the shore of URRL to record meteorological data (windspeed, solar radiation, etc.).

Caution should be exercised in sampling anywhere in the vicinity of the polynya due to shallow and likely unsafe ice conditions.

Outside of the monitoring activities above, winter performance is a concern with respect to solar aeration. Medora indicates their units perform satisfactorily in inclement weather, but do not demonstrate winter performance except for noting observations obtained from their electronic logs[15]. We also could not find any peer-reviewed case-study articles on the use of solar technology for winter oxygenation of lakes, though many articles exists for aeration of wastewater treatment facilities and summer destratification to prevent algal blooms. The pilot-testing component discussed above should meet this need.

[15] Electronic logs from machines indicate they run 24 hours a day, 7 days a week, and 365 days a year at 98% full speed in most of the U.S. and Canada.

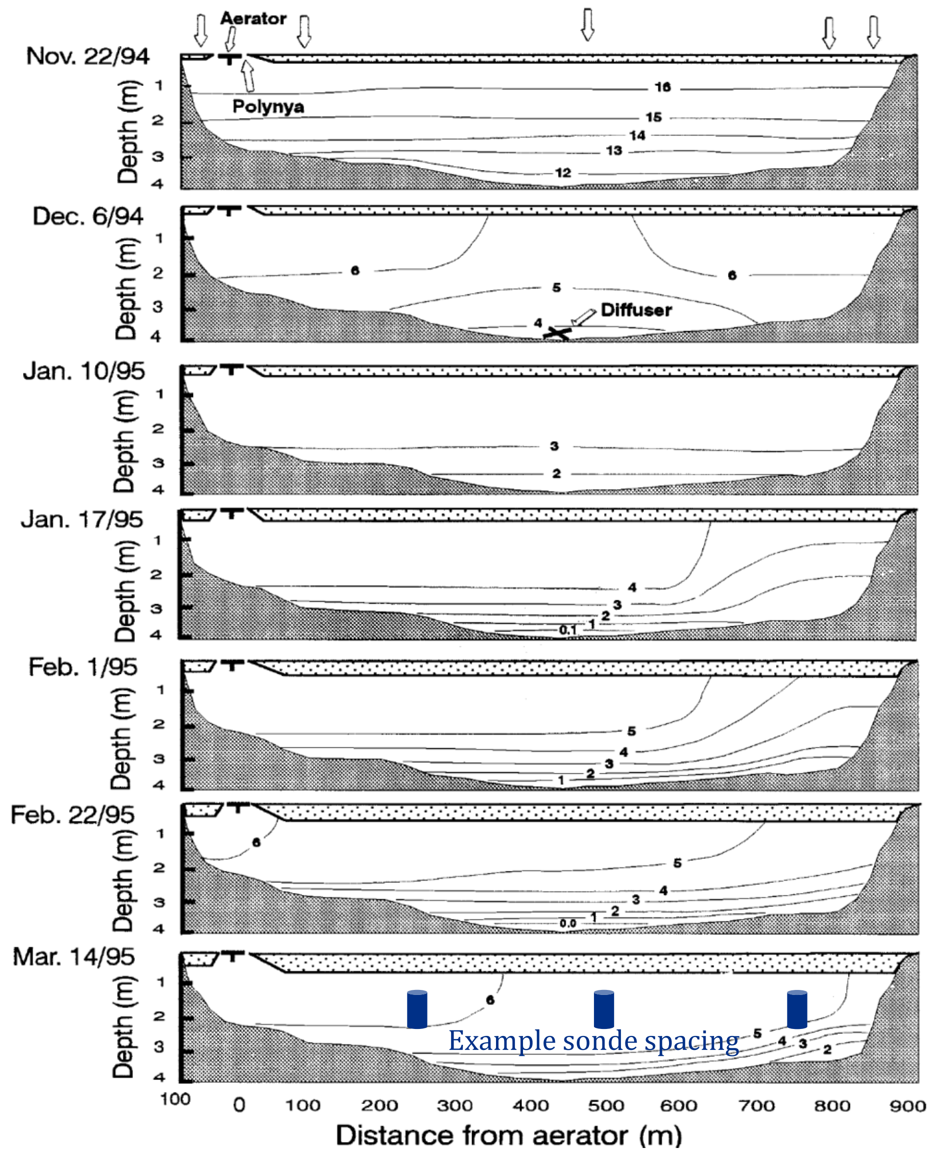

Figure 7-2
Example oxygen isopleths (Miller, Mackay, & Walty, 2001) and sonde spacing for monitoring

Logistical issues need to be addressed ahead of the pilot study. One consideration is whether the units would need to be removed from the lake during the summer months to achieve wilderness objectives, or prior to ice-off to prevent ice-damage. Removal of each unit is not a trivial procedure; units weigh approximately 1,000 lbs and are 15 ft in diameter. Additionally, the unit's minimum floating depth is approximately 3.5 ft before the draft intake plate hits the bottom, so they would have to be lifted onto a large boat to be transported to shore (or removed with a helicopter).

Other potential issues are liability. If there is any chance that snowmobiles or cross-country skiers access the lake in the winter, it is important to have proper signage regarding open water or unsafe ice. The manufacturer's understanding of this issue is that under maritime law, which applies to navigable waters, there is no liability for "aids to ecology" (SolarBees®) in a lake, similar as "aids to navigation" (No Wake sign), if they are placed with permission from the lake authority.

7.3 Data Collection to Support Other Alternatives

Data gaps for the other two alternatives also exist and should be addressed while piloting the SolarBees® in FY2020. Information necessary to assess whether the tributary diversion/point of inflow modification (Alternative 2) or dredging or volume enhancement (Alternative 3) are feasible include:

- Alternative 2 – Winter monitoring of flow and dissolved oxygen concentrations in Shambow Pond, including the alluvial fan springs or seeps west of Shambow Pond, and Widgeon Pond are necessary to assess flow rates available for diversion and to be sure that the water delivered to the center of URRL is suitably oxygenated. Streamflow and DO measurements at other inflow points are also recommended. Observations should be made using field methods specifically designed for measuring streamflow during winter (see https://pubs.usgs.gov/wsp/0187/report.pdf). Monitoring should also include Odell Creek if this is a valid diversion source. Topographic surveys will also be required along the pipeline alignment(s) to move this alternative into design.

- Alternative 3 – Prior to implementing any dredging activity on URRL, sediment traps should be deployed at multiple locations (in duplicate; recommend at a minimum one trap in the northern, southwestern, and south eastern parts of the lake) using the procedures outlined in Bloesch and Burns (1980) to characterize rates of sediment resuspension and deposition. A 4-inch PVC trap with length to length ratio of 5 or greater will be satisfactory to do this and should be operated over at least one open water season. These will help address the primary concern that wind may redistribute sediment within the lake and fill dredged areas, negating the original improvements created by the operation.

Due to the sensitivity of the site and the species of concern, it is recommended that appropriate management and permitting agencies be notified about the ongoing monitoring or pilot study activities.

Section 8
Conclusion

This section contains our final summary and conclusions, including recommendations, for URRL. Over 20 alternatives were initially identified and prioritized that enhanced oxygen exchange or modified bathymetry or circulation. Based on screening procedures that included environmental benefit, constructability, cost, visual and auditory aesthetics, operation and maintenance, reliability, policy or permitting requirements, and habitat connectivity, three alternatives were selected for conceptual development that were believed to be feasible for lake-wide implementation. The final recommended alternatives include the following:

- Alternative 1 – Mechanical aeration with solar aerators, which proposes to use solar aerators, first in a rental piloting program, and then in full-scale operation (pending outcomes) to oxygenate the deeper water at the center of URRL.
- Alternative 2 – Tributary diversion and point of inflow modification, which proposes to divert existing water from one or more tributary inflows to the center of the lake using a gravity pipeline to provide oxygenated water at deeper depths.
- Alternative 3 – Dredging or lake modification, which proposes to increase depth near the tributary mouths, or the overall lake depth, such that these locations meet both the oxygen and depth criterion.

Of the alternatives identified above, Alternative 1 is recommended for URRL since it is believed to have least impact to the wilderness character of the site and the best chance of success. Alternative 2 is also very attractive in that it is easy to construct and reliable but may be difficult to implement from a wilderness perspective. Alternative 3 is the most expensive and is believed to be almost impossible with respect to MRA and permitting.

Costs for three alternatives are shown in Table 8-1. Overall, aeration was the cheapest and perhaps most reliable method, and it is the only alternative that physically enhances oxygen exchange in URRL.

Table 8-1 Overall summary of costs for each alternative

Alternative	Estimated Option Cost ($)
Alternative 1 – Aeration	$145,299
Alternative 2 – Pipeline	$260,262
Alternative 3 - Dredging	$2,324,375

Finally, a pilot study and monitoring program was recommended that will include the rental and installation of a solar-powered aerator during the winter of FY2020 that will be used improve lake conditions and allow performance monitoring of the implementation to understand next steps in meeting the stated objectives for the project. The above activities are believed essential for improving under-ice winter conditions in the lake and provide several avenues to ensure the continued persistence of grayling in the Centennial Valley for future generations.

Section 9

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Appendix A

Original Plat Supporting Wilderness Designation

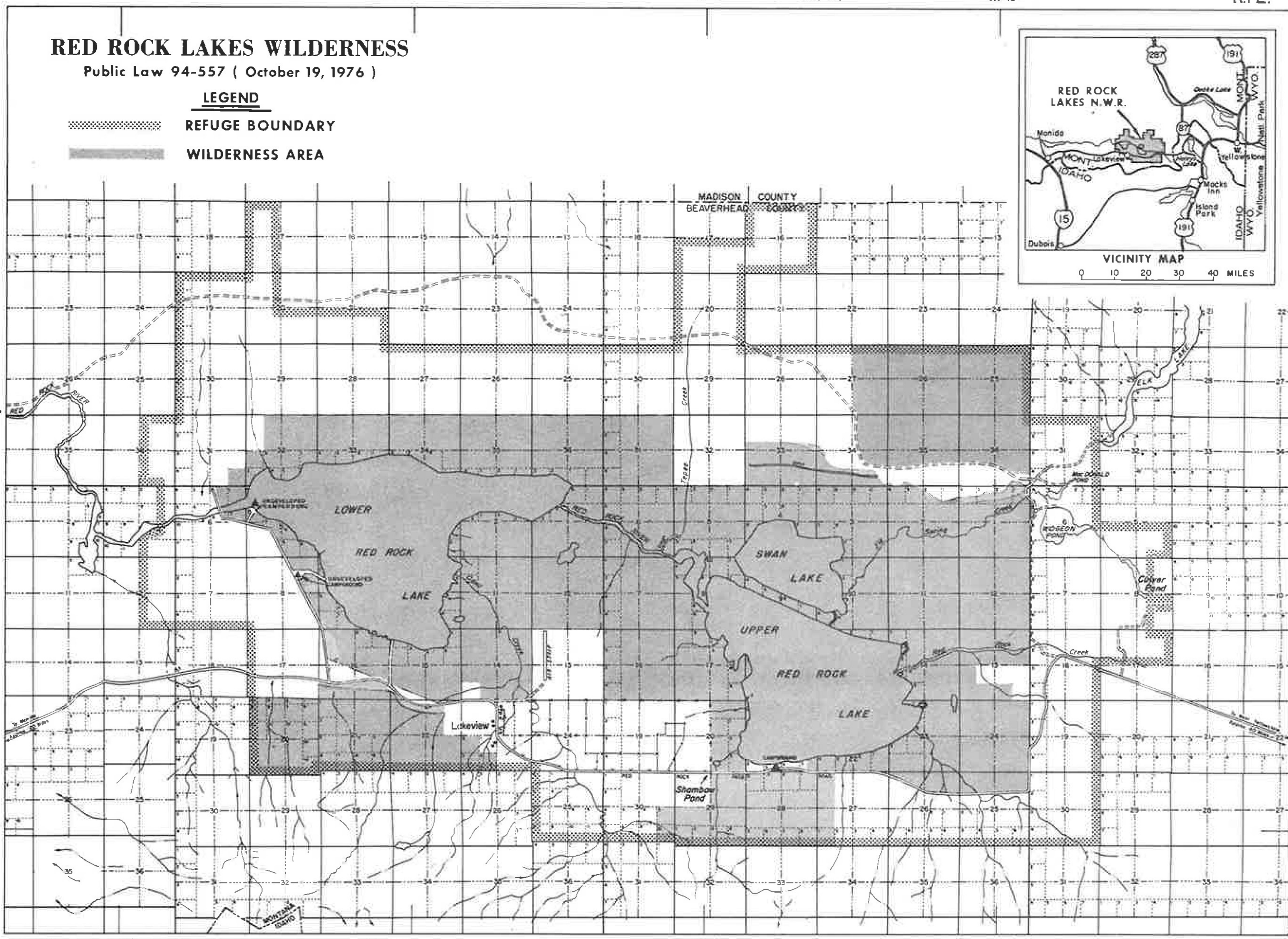
RED ROCK LAKES NATIONAL WILDLIFE REFUGE

BEAVERHEAD COUNTY, MONTANA

UNITED STATES
DEPARTMENT OF THE INTERIOR

UNITED STATES
FISH AND WILDLIFE SERVICE

111°55' R2W. 111°45' R.I W. 111°40' R.I E.



R 3W 111°55' R 2W 111°45' R IW 111°40' R IE 111°35'

COMPILED IN SURVEYS AND MAPS FROM
SURVEYS BY THE BLM, USGS AND FWS

PRINCIPAL MERIDIAN MONTANA

0 5280 10560 15840 21120 FEET

0 1 2 3 4 MILES

True North, Magnetic N, 17°

MEAN
DECLINATION
1975

DENVER, COLORADO
REVISED: JANUARY, 1979

MARCH, 1977

6R MONT. 177 406

Appendix B

Alternative Screening Score Sheets

CDM Smith

Preliminary Engineering & Feasibility Analysis of Alternative to Improve Winter Habitat in Upper Red Rock Lake									
	CDM Smith/Confluence Team						Stakeholders		
Option	Flynn	Johnson	Lovell	Average	SD	COV	Jaeger	Cutting	Average
Mechanical Aeration - diesel generator	111	103	133	116	16	13%	108	107	108
Mechanical Aeration - wind	128	121	123	124	4	3%	122	107	115
Mechanical Aeration - solar	137	107	126	123	15	12%	123	123	123
Mechanical Aeration - electrical	139	141	141	140	1	1%	127	107	117
Snow Removal	132	0	126	86			117	120	119
Carbon Application (albedo changes)	0	0	96	32			126	0	63
Snow Fencing	0	0	0	0			115	107	111
Vegetation Treatments	0	0	129	43			91	114	103
Ground Source Heat	0	0	144	48			137	102	120
Liquid/pellet/PSA Molecular O2 addition	135	0	144	93			142	0	71
Ice Removal (cutting holes)	132	0	122	85			92	132	112
Pumping water onto ice	0	0	128	43					
Fish Population Manipulation	0	115	124	80					
Dredging (hydraulic/mechanical)	131	140	143	138	6	5%	144	98	121
Lake Outlet Modification (increase volume)	145	131	147	141	9	6%	139	94	117
Blasting at Tributary Inlets	132	119	141	131	11	8%	133	115	124
Lower Lake Dam Operation	0	0	134	45			147	129	138
Sediment Sill/Groins	126	122	115	121	6	5%	107	124	116
Increase Inflows	130	0	151	94			130	148	139
Move Inflow Point of Entry (piping/flume/curtain)	157	120	128	135	19	14%	145	87	116
Restructure Elk Springs Cr. at point of Entry	0	120	155	92			124	88	106
Develop Springs/Pull boards	134	123	140	132	9	7%	136	109	123
Impound Tributary(s)	134	0	137	90			104	97	101
Flood Irrigation (winter return flow)	0	123	0	41			85	106	96
Wells/pumping (mechanical mixing)	133	130	125	129	4	3%	135	93	114
Mechanical mixing (in situ)	129	0	117	82					

Upper Red Rock Lake Decision Matrix: Design Objective of 25 ha total minimum winter habitat (i.e., > 4 mg/L DO and > 1 meter depth)																								Scorer: Kyle Flynn
		Weighted Feasibility	Meet Env. Goal? 0=no, 1=yes		Constructable? 0=no, 1=yes		Cost (Int., O&M) 1=high, 5 = low		Aesth./Footprint 1=large, 5=low		O&M Freq. 1=high, 5=low		Reliability 1=low, 5=high		Policy/Permitting 1=high, 5= low		Connectivity 1=low, 5=high		Immediacy 1=low, 5=high		Tangential Benefit 1=low, 5=high		Risk/Uncertainty 1=high, 5=low	
Alternative	Category[1]	/185	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score
Mechanical Aeration - diesel generator	Aeration	111	25	1	25	1	1	1	4	1	3	2	4	2	3	1	3	3	3	5	3	1	3	4
Mechanical Aeration - electrical	Aeration	139	25	1	25	1	1	1	4	2	3	4	4	5	3	2	3	3	3	5	3	2	3	4
Mechanical Aeration - wind-powered	Aeration	128	25	1	25	1	1	1	4	2	3	3	4	3	3	3	3	3	3	5	3	1	3	4
Mechanical Aeration - solar	Aeration	137	25	1	25	1	1	2	4	4	3	3	4	3	3	3	3	3	3	5	3	1	3	4
Snow Removal	Other	132	25	1	25	1	1	1	4	5	3	1	4	1	3	4	3	3	3	5	3	1	3	5
Snow Fencing	Other	0	25	0	25	1	1	5	4	3	3	2	4	1	3	4	3	1	3	5	3	1	3	5
Vegetation Treatments	Other	0	25	0	25	1	1	4	4	5	3	2	4	1	3	4	3	2	3	4	3	2	3	5
Carbon Application (albedo changes)	Other	0	25	0	25	1	1	1	4	5	3	1	4	1	3	4	3	3	3	5	3	1	3	5
Ground Source Heat	Other	0	25	0	25	1	1	2	4	2	3	4	4	1	3	2	3	4	3	5	3	1	3	5
Liquid/pellet/PSA Molecular O_2 addition	Other	135	25	1	25	1	1	1	4	1	3	2	4	5	3	2	3	5	3	5	3	1	3	5
Ice Removal (cutting holes)	Other	132	25	1	25	1	1	1	4	5	3	1	4	1	3	4	3	3	3	5	3	1	3	5
Pumping water onto ice	Other	0	25	0	25	1	1	2	4	4	3	4	4	3	3	4	3	2	3	5	3	1	3	3
Fish Population Manipulation	Other	0	25	0	25	0	1	5	4	5	3	1	4	1	3	4	3	1	3	5	3	2	3	5
Dredging (suction/mechanical)	Depth/Volume Modification	131	25	1	25	1	1	2	4	4	3	3	4	3	3	2	3	1	3	5	3	2	3	4
Dam Modification (increase volume)	Depth/Volume Modification	145	25	1	25	1	1	1	4	3	3	5	4	4	3	1	3	4	3	5	3	3	3	4
Blasting at Tributary Inlets	Depth/Volume Modification	132	25	1	25	1	1	3	4	4	3	3	4	3	3	2	3	1	3	5	3	2	3	4
Lower Lake Dam Operation	Depth/Volume Modification	0	25	0	25	1	1	5	4	5	3	3	4	1	3	5	3	1	3	5	3	1	3	5
Sediment Sill/Groins	Depth/Volume Modification	126	25	1	25	1	1	2	4	3	3	3	4	2	3	2	3	1	3	5	3	3	3	4
Increase Inflows	Lake Circulation	130	25	1	25	1	1	2	4	3	3	5	4	3	3	3	3	1	3	3	3	1	3	5
Move Inflow Point of Entry (piping/flume/curtain)	Lake Circulation	157	25	1	25	1	1	2	4	5	3	5	4	4	3	3	3	4	3	5	3	1	3	5
Restructure Elk Springs Cr. at point of Entry	Lake Circulation	0	25	0	25	1	1	5	4	5	3	4	4	1	3	4	3	1	3	5	3	2	3	5
Develop Springs/Pull boards	Lake Circulation	134	25	1	25	1	1	3	4	5	3	4	4	1	3	3	3	1	3	5	3	1	3	5
Impound Tributary(s)	Lake Circulation	134	25	1	25	1	1	2	4	4	3	4	4	3	3	1	3	2	3	5	3	1	3	5
Flood Irrigation (winter return flow)	Lake Circulation	0	25	0	25	1	1	5	4	5	3	5	4	1	3	3	3	2	3	4	3	1	3	5
Wells/pumping (mechanical mixing)	Lake Circulation	133	25	1	25	1	1	2	4	3	3	4	4	3	3	1	3	3	3	5	3	1	3	5
Mechanical mixing (in situ)	Lake Circulation	129	25	1	25	1	1	1	4	3	3	4	4	3	3	3	3	3	3	5	3	1	3	2

[1] Aeration could be either electric or pnematic aeration using a variety of technologies (bubblers/air injection, splashers/surface aerators/aspirating pumps, pump and baffle)

Immediacy; can be implemented immediately; without further study

Aesthetic/Footprint - long term footprint; not during construction

Reliability - how reliable the technology is during winter over long term operation

Risk/Uncertainty - adverse or unknown/uncertain risks

Upper Red Rock Lake Decision Matrix: Design Objective of 25 ha total minimum winter habitat (i.e., > 4 mg/L DO and > 1 meter depth) Scorer: Ted Johnson

Alternative	Category[1]	Weighted Feasibility /185	Meet Env. Goal? 0=no, 1=yes		Constructable? 0=no, 1=yes		Cost (Int., O&M) 1=high, 5 = low		Aesth./Footprint 1=large, 5=low		O&M Freq. 1=high, 5=low		Reliability 1=low, 5=high		Policy/Permitting 1=high, 5= low		Connectivity 1=low, 5=high		Immediacy 1=low, 5=high		Tangential Benefit 1=low, 5=high		Risk/Uncertainty 1=high, 5=low	
			Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score
Mechanical Aeration - diesel generator	Aeration	103	25	1	25	1	1	1	4	2	3	1	4	2	3	1	3	3	3	5	3	1	3	1
Mechanical Aeration - electrical	Aeration	141	25	1	25	1	1	3	4	4	3	3	4	3	3	3	3	3	3	5	3	1	3	5
Mechanical Aeration - wind-powered	Aeration	121	25	1	25	1	1	3	4	2	3	2	4	3	3	2	3	3	3	5	3	1	3	3
Mechanical Aeration - solar	Aeration	107	25	1	25	1	1	3	4	2	3	2	4	1	3	2	3	3	3	5	3	1	3	1
Snow Removal	Other	0	25	0	25	1	1	3	4	5	3	1	4	3	3	4	3	3	3	3	3	4	3	5
Snow Fencing	Other	0	25	0	25	1	1	5	4	2	3	3	4	3	3	3	3	3	3	3	3	4	3	5
Vegetation Treatments	Other	0	25	0	25	1	1	3	4	5	3	2	4	3	3	2	3	3	3	2	3	4	3	3
Carbon Application (albedo changes)	Other	0	25	0	25	0	1	3	4	5	3	2	4	2	3	3	3	3	3	3	3	1	3	1
Ground Source Heat	Other	0	25	0	25	1	1	1	4	2	3	3	4	2	3	3	3	3	3	3	3	1	3	3
Liquid/pellet/PSA Molecular O_2 addition	Other	0	25	0	25	1	1	2	4	5	3	2	4	3	3	3	3	3	3	5	3	1	3	3
Ice Removal (cutting holes)	Other	0	25	0	25	1	1	3	4	4	3	1	4	3	3	3	3	3	3	3	3	1	3	3
Pumping water onto ice	Other	0	25	0	25	1	1	1	4	3	3	3	4	4	3	2	3	5	3	5	3	3	3	2
Fish Population Manipulation	Other	115	25	1	25	1	1	1	4	1	3	3	4	3	3	1	3	3	3	4	3	3	3	2
Dredging (suction/mechanical)	Depth/Volume Modification	140	25	1	25	1	1	3	4	4	3	5	4	2	3	3	3	3	3	4	3	2	3	4
Dam Modification (increase volume)	Depth/Volume Modification	131	25	1	25	1	1	3	4	3	3	2	4	3	3	4	3	3	3	3	3	3	3	3
Blasting at Tributary Inlets	Depth/Volume Modification	119	25	1	25	1	1	2	4	2	3	4	4	2	3	2	3	3	3	4	3	2	3	2
Lower Lake Dam Operation	Depth/Volume Modification	0	25	1	25	0	1	3	4	4	3	3	4	3	3	3	3	3	3	4	3	3	3	3
Sediment Sill/Groins	Depth/Volume Modification	122	25	1	25	1	1	1	4	2	3	4	4	3	3	2	3	3	3	3	3	2	3	3
Increase Inflows	Lake Circulation	0	25	0	25	0	1		4	4	3	3	4	3	3	3	3	4	3	3	3	4	3	2
Move Inflow Point of Entry (piping/flume/curtain)	Lake Circulation	120	25	1	25	1	1	2	4	2	3	3	4	3	3	2	3	3	3	4	3	2	3	2
Restructure Elk Springs Cr. at point of Entry	Lake Circulation	120	25	1	25	1	1	1	4	1	3	4	4	2	3	1	3	3	3	3	3	4	3	4
Develop Springs/Pull boards	Lake Circulation	123	25	1	25	1	1	2	4	3	3	2	4	2	3	2	3	3	3	2	3	4	3	4
Impound Tributary(s)	Lake Circulation	0	25	0	25	1	1	1	4	2	3	2	4	3	3	1	3	3	3	4	3	3	3	3
Flood Irrigation (winter return flow)	Lake Circulation	123	25	1	25	1	1	2	4	1	3	4	4	4	3	2	3	3	3	3	3	2	3	3
Wells/pumping (mechanical mixing)	Lake Circulation	130	25	1	25	1	1	1	4	3	3	1	4	4	3	2	3	3	3	5	3	2	3	4
Mechanical mixing (in situ)	Lake Circulation	0	25	0	25	1	1	2	4	4	3	1	4	3	3	2	3	3	3	4	3	2	3	3

[1] Aeration could be either electric or pnematic aeration using a variety of technologies (bubblers/air injection, splashers/surface aerators/aspirating pumps, pump and baffle)

Upper Red Rock Lake Decision Matrix: Design Objective of 25 ha total minimum winter habitat (i.e., > 4 mg/L DO and > 1 meter depth)																									Scorer: Jim Lovell
		Weighted Feasibility	Meet Env. Goal? 0=no, 1=yes		Constructable? 0=no, 1=yes		Cost (Int., O&M) 1=high, 5 = low		Aesth./Footprint 1=large, 5=low		O&M Freq. 1=high, 5=low		Reliability 1=low, 5=high		Policy/Permitting 1=high, 5= low		Connectivity 1=low, 5=high		Immediacy 1=low, 5=high		Tangential Benefit 1=low, 5=high		Risk/Uncertainty 1=high, 5=low	
Alternative	**Category[1]**	/185	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score
Mechanical Aeration - diesel generator	Aeration	133	25	1	25	1	1	3	4	3	3	2	4	5	3	1	3	1	3	5	3	2	3	5
Mechanical Aeration - electrical	Aeration	141	25	1	25	1	1	2	4	3	3	4	4	5	3	2	3	1	3	5	3	2	3	5
Mechanical Aeration - wind-powered	Aeration	123	25	1	25	1	1	2	4	2	3	3	4	3	3	3	3	1	3	5	3	2	3	3
Mechanical Aeration - solar	Aeration	126	25	1	25	1	1	3	4	1	3	4	4	3	3	3	3	1	3	5	3	2	3	4
Snow Removal	Other	126	25	1	25	1	1	2	4	5	3	1	4	3	3	5	3	1	3	4	3	1	3	2
Snow Fencing	Other	0	25	0	25	1	1	1	4	2	3	4	4	1	3	3	3	1	3	4	3	1	3	1
Vegetation Treatments	Other	129	25	1	25	1	1	2	4	5	3	1	4	3	3	4	3	1	3	5	3	1	3	3
Carbon Application (albedo changes)	Other	96	25	1	25	1	1	1	4	2	3	1	4	1	3	2	3	1	3	4	3	1	3	2
Ground Source Heat	Other	144	25	1	25	1	1	4	4	4	3	4	4	5	3	3	3	1	3	5	3	1	3	4
Liquid/pellet/PSA Molecular O_2 addition	Other	144	25	1	25	1	1	3	4	5	3	2	4	5	3	3	3	1	3	5	3	1	3	5
Ice Removal (cutting holes)	Other	122	25	1	25	1	1	2	4	4	3	1	4	3	3	5	3	1	3	4	3	1	3	2
Pumping water onto ice	Other	128	25	1	25	1	1	2	4	5	3	2	4	2	3	4	3	1	3	5	3	1	3	3
Fish Population Manipulation	Other	124	25	1	25	1	1	2	4	5	3	1	4	1	3	3	3	1	3	5	3	4	3	2
Dredging (suction/mechanical)	Depth/Volume Modification	143	25	1	25	1	1	3	4	5	3	3	4	4	3	2	3	3	3	5	3	2	3	3
Dam Modification (increase volume)	Depth/Volume Modification	147	25	1	25	1	1	5	4	3	3	4	4	5	3	1	3	3	3	5	3	3	3	4
Blasting at Tributary Inlets	Depth/Volume Modification	141	25	1	25	1	1	2	4	4	3	4	4	4	3	3	3	3	3	5	3	1	3	3
Lower Lake Dam Operation	Depth/Volume Modification	134	25	1	25	1	1	2	4	5	3	5	4	2	3	5	3	1	3	5	3	1	3	1
Sediment Sill/Groins	Depth/Volume Modification	115	25	1	25	1	1	3	4	3	3	4	4	2	3	3	3	1	3	3	3	1	3	2
Increase Inflows	Lake Circulation	151	25	1	25	1	1	3	4	5	3	4	4	3	3	3	3	4	3	5	3	3	3	3
Move Inflow Point of Entry (piping/flume/curtain)	Lake Circulation	128	25	1	25	1	1	2	4	4	3	3	4	3	3	3	3	2	3	5	3	1	3	2
Restructure Elk Springs Cr. at point of Entry	Lake Circulation	155	25	1	25	1	1	2	4	4	3	5	4	3	3	4	3	3	3	5	3	4	3	4
Develop Springs/Pull boards	Lake Circulation	140	25	1	25	1	1	3	4	5	3	4	4	4	3	3	3	2	3	4	3	1	3	3
Impound Tributary(s)	Lake Circulation	137	25	1	25	1	1	4	4	5	3	4	4	3	3	1	3	1	3	5	3	3	3	3
Flood Irrigation (winter return flow)	Lake Circulation	0	25	0	25	1	1	2	4	4	3	4	4	1	3	4	3	1	3	3	3	3	3	1
Wells/pumping (mechanical mixing)	Lake Circulation	125	25	1	25	1	1	3	4	4	3	4	4	2	3	3	3	1	3	5	3	1	3	2
Mechanical mixing (in situ)	Lake Circulation	117	25	1	25	1	1	2	4	3	3	3	4	2	3	3	3	1	3	5	3	1	3	2

[1] Aeration could be either electric or pnematic aeration using a variety of technologies (bubblers/air injection, splashers/surface aerators/aspirating pumps, pump and baffle)

Upper Red Rock Lake Decision Matrix: Design Objective of 25 ha total minimum winter habitat (i.e., > 4 mg/L DO and > 1 meter depth)																								Scorer: Matt Jaeger
			Meet Env. Goal? 0=no, 1=yes		Constructable? 0=no, 1=yes		Cost 1=high, 5 = low		Aesth./Footprint 1=large, 5=low		O & M 1=high, 5=low		Reliability 1=low, 5=high		Policy/Permitting 1=high, 5= low		Connectivity 1=low, 5=high		Immediacy 1=low, 5=high		MOS/Tangential 1=low, 5=high	
Alternative	Category	Feasibility /250	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score
Mechanical Aeration - diesel generator	Aeration	108	25	1	25	1	2	2	4	2	3	1	4	1	3	1	3	5	3	3	3	4
Mechanical Aeration - electrical	Aeration	127	25	1	25	1	2	2	4	3	3	1	4	4	3	2	3	5	3	3	3	4
Mechanical Aeration - windmill	Aeration	122	25	1	25	1	2	5	4	2	3	1	4	3	3	1	3	5	3	3	3	4
Mechanical Aeration - solar	Aeration	123	25	1	25	1	2	4	4	2	3	1	4	3	3	2	3	5	3	3	3	4
Snow Removal	Other	117	25	1	25	1	2	3	4	3	3	1	4	4	3	1	3	5	3	2	3	2
Snow Fencing	Other	115	25	1	25	1	2	5	4	2	3	1	4	2	3	4	3	5	3	2	3	1
Vegetation Treatments	Other	91	25	1	25	1	2	2	4	2	3	1	4	2	3	1	3	3	3	1	3	1
Carbon Application (albedo changes)	Other	126	25	1	25	1	2	4	4	3	3	3	4	2	3	4	3	5	3	3	3	1
Ground Source Heat	Other	137	25	1	25	1	2	4	4	2	3	5	4	5	3	2	3	5	3	4	3	1
Liquid/pellet O_2 addition	Other	142	25	1	25	1	2	3	4	5	3	2	4	3	3	4	3	5	3	4	3	3
Ice Removal	Other	92	25	1	25	1	2	3	4	2	3	1	4	1	3	1	3	3	3	2	3	1
Dredging (suction/mechanical)	Depth/Volume Modification	144	25	1	25	1	2	3	4	3	3	5	4	4	3	1	3	5	3	5	3	4
Dam	Depth/Volume Modification	139	25	1	25	1	2	1	4	1	3	5	4	5	3	1	3	5	3	5	3	5
Blasting at Tributary Inlets	Depth/Volume Modification	133	25	1	25	1	2	4	4	3	3	4	4	3	3	3	3	2	3	5	3	3
Lower Lake Dam Operation	Depth/Volume Modification	147	25	1	25	1	2	5	4	5	3	5	4	4	3	5	3	1	3	5	3	1
Sediment Sill/Groins	Depth/Volume Modification	107	25	1	25	1	2	2	4	2	3	5	4	3	3	1	3	1	3	2	3	2
Increase Inflows	Lake Circulation	130	25	1	25	1	2	5	4	5	3	3	4	2	3	4	3	2	3	3	3	2
Move Inflow Point of Entry	Lake Circulation	145	25	1	25	1	2	3	4	3	3	4	4	5	3	2	3	4	3	4	3	5
Restructure ESC at point of Entry	Lake Circulation	124	25	1	25	1	2	3	4	2	3	5	4	3	3	1	3	2	3	5	3	3
Develop Springs/Pull boards	Lake Circulation	136	25	1	25	1	2	4	4	4	3	4	4	5	3	4	3	1	3	3	3	2
Impound Tributary(s)	Lake Circulation	104	25	1	25	1	2	1	4	1	3	4	4	3	3	1	3	1	3	4	3	2
Flood Irrigation	Lake Circulation	85	25	1	25	1	2	4	4	2	3	1	4	1	3	1	3	1	3	1	3	1
Wells/pumping	Lake Circulation	135	25	1	25	1	2	3	4	3	3	3	4	4	3	3	3	4	3	3	3	4
Piping/flume/curtain	Lake Circulation	116	25	1	25	1	2	2	4	2	3	4	4	3	3	1	3	3	3	4	3	2

Upper Red Rock Lake Decision Matrix: Design Objective of 25 ha total minimum winter habitat (i.e., > 4 mg/L DO and > 1 meter depth) Scorer: Kyle Cutting

		Feasibility	Meet Env. Goal? 0=no, 1=yes		Constructable? 0=no, 1=yes		Cost 1=high, 5 = low		Aesth./Footprint 1=large, 5=low		O & M 1=high, 5=low		Reliability 1=low, 5=high		Policy/Permitting 1=high, 5= low		Connectivity 1=low, 5=high		Immediacy 1=low, 5=high		MOS/Tangential 1=low, 5=high	
Alternative	**Category**	**/250**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**	**Weight**	**Score**
Mechanical Aeration - diesel generator	Aeration	107	25	1	25	1	2	1	4	1	3	2	4	3	3	1	3	3	3	5	3	2
Mechanical Aeration - electrical	Aeration	107	25	1	25	1	2	1	4	1	3	2	4	3	3	1	3	3	3	5	3	2
Mechanical Aeration - windmill	Aeration	107	25	1	25	1	2	1	4	1	3	2	4	3	3	1	3	3	3	5	3	2
Mechanical Aeration - solar	Aeration	123	25	1	25	1	2	1	4	1	3	2	4	4	3	3	3	3	3	5	3	4
Snow Removal	Other	120	25	1	25	1	2	1	4	5	3	2	4	3	3	4	3	1	3	3	3	2
Snow Fencing	Other	107	25	1	25	1	2	3	4	2	3	4	4	1	3	2	3	1	3	1	3	5
Vegetation Treatments	Other	114	25	1	25	1	2	2	4	4	3	3	4	2	3	1	3	1	3	3	3	4
Carbon Application (albedo changes)	Other	0	25	1	25	0	2	2	4	5	3	3	4	1	3	3	3	1	3	2	3	3
Ground Source Heat	Other	102	25	1	25	1	2	1	4	4	3	2	4	1	3	1	3	1	3	2	3	4
Liquid/pellet O_2 addition	Other	0	25	1	25	0	2	2	4	5	3	3	4	1	3	3	3	1	3	2	3	2
Ice Removal	Other	132	25	1	25	1	2	2	4	5	3	1	4	4	3	5	3	1	3	5	3	2
Dredging (suction/mechanical)	Depth/Volume Modification	98	25	1	25	1	2	1	4	1	3	2	4	3	3	1	3	1	3	3	3	3
Dam	Depth/Volume Modification	94	25	1	25	1	2	1	4	1	3	4	4	2	3	1	3	1	3	1	3	3
Blasting at Tributary Inlets	Depth/Volume Modification	115	25	1	25	1	2	4	4	3	3	2	4	3	3	3	3	1	3	3	3	2
Lower Lake Dam Operation	Depth/Volume Modification	129	25	1	25	1	2	5	4	5	3	5	4	1	3	5	3	1	3	1	3	3
Sediment Sill/Groins	Depth/Volume Modification	124	25	1	25	1	2	5	4	4	3	3	4	3	3	3	3	1	3	2	3	3
Increase Inflows	Lake Circulation	148	25	1	25	1	2	4	4	5	3	2	4	4	3	4	3	2	3	5	3	5
Move Inflow Point of Entry	Lake Circulation	87	25	1	25	1	2	2	4	1	3	2	4	2	3	1	3	1	3	1	3	2
Restructure ESC at point of Entry	Lake Circulation	88	25	1	25	1	2	1	4	1	3	3	4	2	3	1	3	1	3	1	3	2
Develop Springs/Pull boards	Lake Circulation	109	25	1	25	1	2	3	4	3	3	4	4	2	3	1	3	1	3	3	3	2
Impound Tributary(s)	Lake Circulation	97	25	1	25	1	2	2	4	2	3	3	4	2	3	1	3	1	3	2	3	2
Flood Irrigation	Lake Circulation	106	25	1	25	1	2	5	4	2	3	2	4	2	3	3	3	1	3	2	3	2
Wells/pumping	Lake Circulation	93	25	1	25	1	2	1	4	3	3	1	4	2	3	1	3	1	3	2	3	2
Piping/flume/curtain	Lake Circulation	132	25	1	25	1	2	2	4	2	3	2	4	4	3	2	3	5	3	5	3	4

Appendix C

Opinion of Probable Construction Costs (Level 5)

CDM Smith

Upper Red Rock Lake, MT:

Preliminary Engineering and Feasibility Analysis to Improve Winter Habitat for Arctic Grayling

Alternative 1 - Bubbler Aeration Estimate

Material Estimates	Quantity	Unit Cost ($)	Cost ($)	Source or Assumption
Electrical service (installed)	1	$ 85,000	$ 85,000	Vigilante Electric (personal communication)
Compressor slab	1	$ 10,000	$ 10,000	Lump sum estimate
Compressor(s) – 1 @ 4 HP (33 CFM)	1	$ 9,349.00	$ 9,349	Vendor price sheet/quote
Diffusers 10 @ (2,5 CFM minimum)	10	$ 205.00	$ 2,050	Vendor price sheet/quote
3/4" Self-Sinking Tubing (max length)	50,000	$ 2.28	$ 114,000	Vendor price sheet/quote
Installation (labor)	152	$ 160.00	$ 24,320	Contract labor at $160/hr (4 man crew for construction); Electrical(2 man crew) $100/hr
Equipment | ODCs	1	11,142	$ 11,142	
Contingency (10%)			$ 24,471.90	
Total			**$ 280,333**	

Labor Estimates	Hours	Hourly Rate ($)	Cost ($)	Source
Set diffusers	40	$ 160	$ 6,400	2 days travel, 3 days installation
Run tubing	40	$ 160	$ 6,400	2 days travel, 3 days installation
Set compressor unit	24	$ 160	$ 3,840	2 days travel, 1 day installation
Tie in electrical/plumbing	24	$ 160	$ 3,840	2 days travel, 1 days installation
Labor total	24	$ 160	$ 20,480	

Equipment | ODCs	Days	Daily Rate ($)	Cost ($)	Assumption
Boat Rental	10	$ 250	$ 2,500	
Per diem	58	$ 149	$ 8,642	https://www.federalpay.org/perdiem/2019/montana
Other			$ -	
Equipment | ODC Ttotal			$ 11,142	

ESTIMATE PROVIDER
Vigilante Electric Co-Op Inc.

CONTACT
Gary Ferris
Dillon Office: (800) 221-8271

LOCATION
Lakeview, MT

EXTENSION TYPE
direct-buried by provider

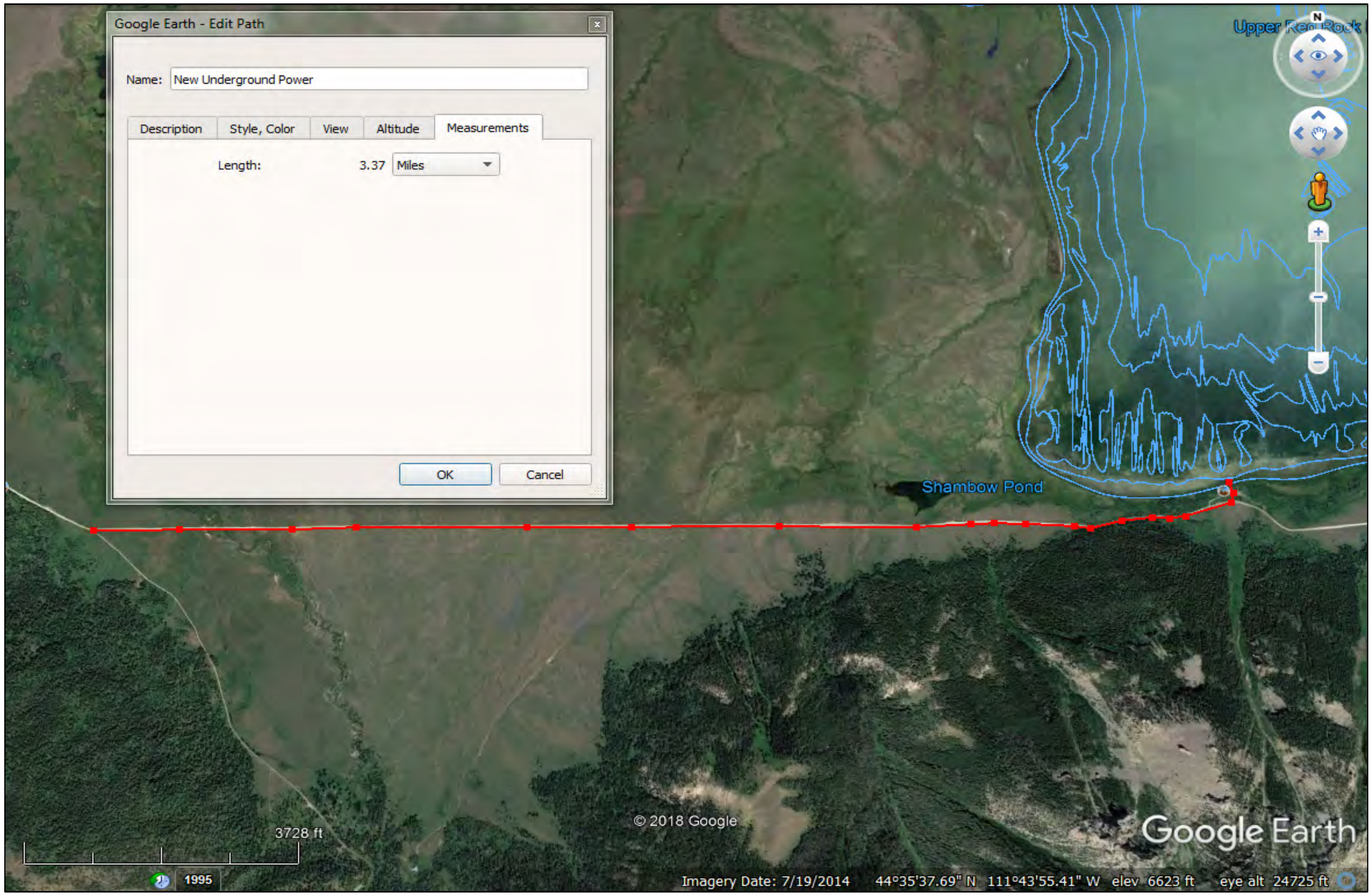
RATE (USD)
$25,000 / mi

TOTAL DISTANCE
17,790 ft

TOTAL DISTANCE
3.37 mi

TOTAL ESTIMATED COST
$84,233 USD

ADDITIONAL INFO
$38/mo min, 5-year contract
$100 co-op membership fee



Vertex Water Features
Pond and Lake Aeration

2017 Retail Prices
Systems and Parts

Prices Effective March 1, 2017

Table of Contents

Aeration Warranties

AirStation™ Diffuser Assembly: 5 Years

Brookwood Compressor Systems: 3 Years

BottomLine™ Tubing: 15 Years

QuietAir™ Cabinets: Lifetime against rust

844-432-4303 • www.vertexwaterfeatures.com

XL2, XL2SW & HighFlow Systems

PART #	AIR STATIONS	QUIETAIR CABINET	HP	CFM	CYL.	RETAIL
AIR 1	1	Small	1/3	2.5	1	$1617.00
AIR 1 230	1	Small	1/3	2.5	1	$1628.00
AIR 1+	2	Small	1/3	2.5	1	$1932.00
AIR 1+ 230	2	Small	1/3	2.5	1	$1943.00
AIR 2	2	Medium	1/2	4.3	2	$2239.00
AIR 2 230	2	Medium	1/2	4.3	2	$2249.00
AIR 3	3	Medium	1/2	4.3	2	$2429.00
AIR 3 230	3	Medium	1/2	4.3	2	$2439.00
AIR 4	4	Large	1	8.6	4	$3784.00
AIR 4 230	4	Large	1	8.6	4	$3805.00
AIR 5	5	Large	1	8.6	4	$3954.00
AIR 5 230	5	Large	1	8.6	4	$3975.00
AIR 6	6	Large	1	8.6	4	$4152.00
AIR 6 230	6	Large	1	8.6	4	$4173.00
HF 2	2	Medium	3/4	5.6	2	$2496.00
HF 2 230	2	Medium	3/4	5.6	2	$2506.00
HF 3	3	Medium	3/4	5.6	2	$2747.00
HF 3 230	3	Medium	3/4	5.6	2	$2757.00
HF 3+	4	Medium	3/4	5.6	2	$2952.00
HF 3+ 230	4	Medium	3/4	5.6	2	$2962.00
HF 4	4	Large	1 1/2	11.2	4	$4059.00
HF 4 230	4	Large	1 1/2	11.2	4	$4080.00
HF 5	5	Large	1 1/2	11.2	4	$4259.00
HF 5 230	5	Large	1 1/2	11.2	4	$4280.00
HF 6	6	Large	1 1/2	11.2	4	$4498.00
HF 6 230	6	Large	1 1/2	11.2	4	$4519.00
HF 7	7	Large	1 1/2	11.2	4	$4724.00
HF 7 230	7	Large	1 1/2	11.2	4	$4745.00

XL2, XL2SW & HighFlow VBS Systems

VBS Remote Valve Boxes are required and sold separately below

PART #	AIR STATIONS	QUIETAIR CABINET	HP	CFM	CYL.	RETAIL
AIR 1+ VBS	2	Small	1/3	2.5	1	$1811.00
AIR 1+ VBS 230	2	Small	1/3	2.5	1	$1822.00
AIR 2 VBS	2	Medium	1/2	4.3	2	$2150.00
AIR 2 VBS 230	2	Medium	1/2	4.3	2	$2161.00
AIR 3 VBS	3	Medium	1/2	4.3	2	$2307.00
AIR 3 VBS 230	3	Medium	1/2	4.3	2	$2317.00
AIR 4 VBS	4	Large	1	8.6	4	$3605.00
AIR 4 VBS 230	4	Large	1	8.6	4	$3626.00
AIR 5 VBS	5	Large	1	8.6	4	$3768.00
AIR 5 VBS 230	5	Large	1	8.6	4	$3789.00
AIR 6 VBS	6	Large	1	8.6	4	$3994.00
AIR 6 VBS 230	6	Large	1	8.6	4	$4015.00
HF 2 VBS	2	Medium	3/4	5.6	2	$2351.00
HF 2 VBS 230	2	Medium	3/4	5.6	2	$2361.00
HF 3 VBS	3	Medium	3/4	5.6	2	$2544.00
HF 3 VBS 230	3	Medium	3/4	5.6	2	$2555.00
HF 3+ VBS	4	Medium	3/4	5.6	2	$2739.00
HF 3+ VBS 230	4	Medium	3/4	5.6	2	$2750.00
HF 4 VBS	4	Large	1 1/2	11.2	4	$3839.00
HF 4 VBS 230	4	Large	1 1/2	11.2	4	$3860.00
HF 5 VBS	5	Large	1 1/2	11.2	4	$4049.00
HF 5 VBS 230	5	Large	1 1/2	11.2	4	$4070.00
HF 6 VBS	6	Large	1 1/2	11.2	4	$4238.00
HF 6 VBS 230	6	Large	1 1/2	11.2	4	$4259.00
HF 7 VBS	7	Large	1 1/2	11.2	4	$4400.00
HF 7 VBS 230	7	Large	1 1/2	11.2	4	$4421.00

VBS REMOTE VALVE BOX JUNCTION MANIFOLDS

PART #	VALVES	ITEM	RETAIL
DIF520	2	- Fully Assembled - Valve Box - Brass Ball Valves - Aluminum Valve Manifold - Pressure Gauge - Hose Connectors to Bottom Line Tubing - 1" PVC Pipe Adaptor	$328.00
DIF530	3		$395.00
DIF540	4		$429.00
DIF550	5		$468.00
DIF560	6		$544.00
DIF570	7		$660.00
DIF580	8		$696.00

XL4, XL5,LL & HighFlow Systems

PART #	AIR STATIONS	QUIETAIR CABINET	HP	CFM	CYL.	RETAIL
AIR 1XL	1	Small	1/3	2.5	1	$1747.00
AIR 1XL 230	1	Small	1/3	2.5	1	$1758.00
AIR 2XL	2	Medium	1/2	4.3	2	$2461.00
AIR 2XL 230	2	Medium	1/2	4.3	2	$2472.00
AIR 3XL	3	Large	1	8.6	4	$3911.00
AIR 3XL 230	3	Large	1	8.6	4	$3922.00
AIR 4XL	4	Large	1	8.6	4	$4101.00
AIR 4XL 230	4	Large	1	8.6	4	$4122.00
HF 2XL	2	Medium	3/4	5.6	2	$2725.00
HF 2XL 230	2	Medium	3/4	5.6	2	$2735.00
HF 3XL	3	Large	1 1/2	11.2	4	$4115.00
HF 3XL 230	3	Large	1 1/2	11.2	4	$4125.00
HF 4XL	4	Large	1 1/2	11.2	4	$4490.00
HF 4XL 230	4	Large	1 1/2	11.2	4	$4511.00
HF 5XL	5	Large	1 1/2	11.2	4	$4809.00
HF 5XL 230	5	Large	1 1/2	11.2	4	$4830.00
HF 1XL5	1	Medium	3/4	5.6	2	$2339.00
HF 1XL5 230	1	Medium	3/4	5.6	2	$2350.00
HF 2XL5	2	Medium	3/4	5.6	2	$2791.00
HF 2XL5 230	2	Medium	3/4	5.6	2	$2801.00
HF 3XL5	3	Large	1 1/2	11.2	4	$4288.00
HF 3XL5 230	3	Large	1 1/2	11.2	4	$4299.00
HF 4XL5	4	Large	1 1/2	11.2	4	$4649.00
HF 4XL5 230	4	Large	1 1/2	11.2	4	$4670.00

High Efficiency LL HE22 Systems

	PART #	RETAIL
High Efficiency, custom configurable cabinet: (4) 230V compressors 22 CFM. (3) 6" cooling fans. Valved or VBS integrated sound control baffle as required up to 8 outlets. VBS mounting pad included. *AirStations sold separately*	LL HE22 230V	$6657.00
	LL HE22 230V VBS	$6242.00

High Efficiency LL HE33 Systems

	PART #	RETAIL
High Efficiency, custom configurable cabinet: (4) 230V compressors 33 CFM. (3) 7" cooling fans. Valved or VBS integrated sound control baffle as required up to 10 outlets. VBS mounting pad included. *AirStations sold separately*	LL HE33 230V	$9349.00
	LL HE33 230V VBS	$8870.00

XL4, XL5 & HighFlow VBS Systems

VBS Remote Valve Boxes are required and sold separately below

PART #	AIR STATIONS	QUIETAIR CABINET	HP	CFM	CYL.	RETAIL
AIR 2XL VBS	2	Medium	1/2	4.3	2	$2363.00
AIR 2XL VBS 230	2	Medium	1/2	4.3	2	$2373.00
AIR 3XL VBS	3	Large	1	8.6	4	$3795.00
AIR 3XL VBS 230	3	Large	1	8.6	4	$3805.00
AIR 4XL VBS	4	Large	1	8.6	4	$4031.00
AIR 4XL VBS 230	4	Large	1	8.6	4	$4052.00
HF 2XL VBS	2	Medium	3/4	5.6	2	$2587.00
HF 2XL VBS 230	2	Medium	3/4	5.6	2	$2598.00
HF 3XL VBS	3	Large	1 1/2	11.2	4	$4070.00
HF 3XL VBS 230	3	Large	1 1/2	11.2	4	$4080.00
HF 4XL VBS	4	Large	1 1/2	11.2	4	$4347.00
HF 4XL VBS 230	4	Large	1 1/2	11.2	4	$4368.00
HF 5XL VBS	5	Large	1 1/2	11.2	4	$4616.00
HF 5XL VBS 230	5	Large	1 1/2	11.2	4	$4637.00
HF 1XL5 VBS	1	Medium	3/4	5.6	2	$2373.00
HF 1XL5 VBS 230	1	Medium	3/4	5.6	2	$2384.00
HF 2XL5 VBS	2	Medium	3/4	5.6	2	$2587.00
HF 2XL5 VBS 230	2	Medium	3/4	5.6	2	$2598.00
HF 3XL5 VBS	3	Large	1 1/2	11.2	4	$4122.00
HF 3XL5 VBS 230	3	Large	1 1/2	11.2	4	$4133.00
HF 4XL5 VBS	4	Large	1 1/2	11.2	4	$4498.00
HF 4XL5 VBS 230	4	Large	1 1/2	11.2	4	$4519.00

VBS REMOTE VALVE BOX JUNCTION MANIFOLDS

PART #	VALVES	ITEM	RETAIL
DIF520	2	- Fully Assembled - Valve Box - Brass Ball Valves - Aluminum Valve Manifold - Pressure Gauge - Hose Connectors to Bottom Line Tubing - 1" PVC Pipe Adaptor	$328.00
DIF530	3		$395.00
DIF540	4		$429.00
DIF550	5		$468.00
DIF560	6		$544.00
DIF570	7		$660.00
DIF580	8		$696.00

PONDLYFE
NATURAL ~ SAFE ~ EFFECTIVE

Cabinet Colors

Stone | Sand | Garden

Pond-Lyfe and PondLyfe VBS Systems

Specify color when ordering

PART #	AIRSTATIONS	CABINET	HP	CFM	CYL.	RETAIL
PondLyfe 1	(1) XL2 SW	PondLyfe	1/4	2	1	$1268.00
PondLyfe 2	(2) XL1	PondLyfe	1/4	2	1	$1433.00
PondLyfe 3	(3) XL1	PondLyfe	1/4	2	1	$1588.00
PondLyfe 4	(1) XL2 SW (1) XL1	PondLyfe	1/4	2	1	$1523.00
PondLyfe 2 VBS	(2) XL1	PondLyfe	1/4	2	1	$1384.00
PondLyfe 3 VBS	(3) XL1	PondLyfe	1/4	2	1	$1498.00
PondLyfe 4 VBS	(1) XL2 SW (1) XL1	PondLyfe	1/4	2	1	$1451.00

PondLyfe VBS Remote Valve Box Junction Manifolds

PART #	VALVES	ITEM	RETAIL
DIF 520	2	Fully assembled, valve box, brass ball valves, pressure gauge, aluminum valve manifold, hose connectors to bottomline tubing, 1" pvc pipe adaptor	$328.00
DIF 530	3		$395.00

BRITESTAR
BATTERY-FREE SOLAR AERATION

BriteStar Systems

PART #	SOLAR PANELS	AIRSTATIONS	CABINET	VOLTS	CFM	RETAIL
BriteStar 1	(2) 250W	(1) XL2 SW	BriteStar	24	2.5	$3683.00
BriteStar 2	(2) 250W	(2) XL1	BriteStar	24	2.5	$3779.00
BriteStar 3	(2) 250W	(3) XL1	BriteStar	24	2.5	$3875.00
BriteStar 4	(2) 250W	(1) XL2 SW (1) XL1	BriteStar	24	2.5	$3822.00
BriteStar 1 CBN	1 Valve Compressor system only - no AirStations or solar panels included			24	2.5	$1762.00
BriteStar 2 CBN	2 Valve Compressor system only - no AirStations or solar panels included			24	2.5	$1888.00
BriteStar 3 CBN	3 Valve Compressor system only - no AirStations or solar panels included			24	2.5	$2014.00

BottomLine™ Self-Weighted Tubing

For tubing orders of 5000' or more, call for quantity discount

PART #	ID	LENGTH	ITEM	RETAIL
AT050	0.58"	50'	Single Box	$72.00
AT100	0.58"	100'	Single Box	$130.00
AT111	0.58"	500'	Single Spool	$650.00
AT300	0.75"	300'	Single Spool	$685.00
AT400	1.0"	250'	Single Box	$812.00
AT500	0.625"	100'	Single Box	$159.00
AT511	0.625"	500'	Single Spool	$795.00
AT600	1.25"	250'	Single Box	$1160.00
FIT105Z		1/2" barbed insert coupling for AT100		$1.05

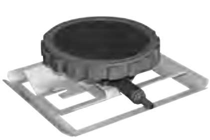
Polyethylene Tubing

PART #	ID	LENGTH	ITEM	RETAIL
AT888		100' Coil 1/2" poly tubing		$51.00
CLP105Z		1/2" stainless steel clamps		$3.00
CLP110Z		3/4" stainless steel clamps		$4.00

CoActive™ Airstation Diffuser Assemblies

PART #	ITEM	MIN. CFM	BEST DEPTHS	RETAIL
ASTNXL1	XL1 AirStation - (1) 9" disk, Stainless Steel base	0.5	4' and deeper	$146.00
ASTN	XL2 AirStation - (2) 9" disks, Stainless Steel base	1.0	9' - 20'	$202.00
ASTNSW	XL2SW AirStation - (2) 9" disks, Stainless Steel base	1.0	4' - 8'	$205.00
ASTNXL	XL4 AirStation - 4) 9" disks with base	2.0	16' and deeper	$322.00
ASTNXL5	XL5 AirStation - (5) 9" disks with base	2.5	8' and deeper	$380.00
DIF109	9" MicronBubble™ diffuser disk: 3/4" MPT. Produces .5 - 1 mm bubbles			$45.00

XL1



Stainless Steel Base
For depths 4' and deeper

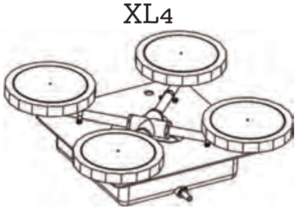
XL2

Stainless Steel Base
For depths between 9' and 20'

XL2SW

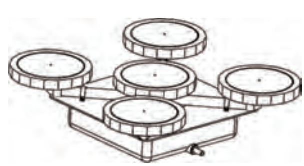
Stainless Steel Base
For depths between 4' and 8'

XL4



For depths 16' and deeper

XL5



For depths 8' and deeper

Sound Kits For Noise Reduction

PART #	ITEM		RETAIL
CBN113	Small Cabinet	Muffler Box, Sound Insulation, Quiet Filter	$295.00
CBN109	Medium Cabinet		$354.00
CBN108	Large Cabinet		$427.00
CBN114	Large Lake Cabinet	Sound Insulation, Quiet Filter	$390.00

Valves & Misc Fittings

PART #	ITEM	RETAIL
VAL429Z	3/8" Brass ball valve	$19.00
HOS104	Adapter Assembly 1/2" Barbed Coupler to 1" PVC	$28.00

In-Cabinet Valve Assemblies

PART #	DESCRIPTION	VALVES	RETAIL
VAL 1	Fully assembled aluminum valve manifold with pressure gauge, pressure relief valve, unions, ball valves, high temperature hose fitting brookwood compressor. For retrofitting rotary vane systems to brookwood compressors	1	$223.00
VAL 2		2	$267.00
VAL 3		3	$313.00
VAL 4		4	$441.00
VAL 5		5	$496.00
VAL 6		6	$524.00
VAL 7		7	$601.00

Replacement Cabinet Keys

PART #	ITEM	MODEL YEAR	RETAIL
BL099Z	Rounded key for older barrel lock	Before 8/11	$20.00
BL200Z	Double sided key for ETL approved lock	8/11 - 8/15	$10.00
BL119Z	Key for ETL approved lock	After 8/15	$5.00

Compressor Services with Bearing Change

PART #	ITEM	RETAIL
COMREP 1 PISTON	Single Piston Compressor Rebuild	$148.00
COMREP 2 PISTON	Duel Piston Compressor Rebuild	$219.00
COMREP 500	Pond-Lyfe Single Piston Compressor Rebuild	$164.00

MICRO LYFE
NATURAL ~ SAFE ~ EFFECTIVE

Pond & Lake Products

PART #	DESCRIPTION	SALE UNIT	RETAIL
MLYBB40	Barley Boss	40 lb. Bag	$86.00
MLYBLP5	Blue Power	One (1) 5 gallon Container	$198.00
MLYCON5	Concentrate Bacteria	One (1) 5 gallon Container	$499.00
MLYCOP5	Complete	One (1) 5 gallon Container	$145.00
MLYDG25	Digester 8oz. soluble packs	25 lb. Pail containing 50 packs	$330.00
MLYSLC5	Sludge Clear	One (1) 5 gallon Container	$152.00

Aeration Replacement Parts

The **representative photos** below and the charts on the following pages match the **parts sticker** found on the back of the Owner's Manual that shipped with the compressor cabinet. If you no longer have the Owner's Manual, look on the silver ETL sticker inside the cabinet for the Warranty Code so that we can look up your system.

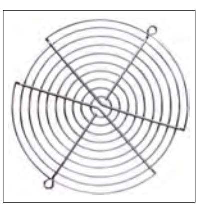
A Liquid Filled Pressure Gauge

B Replacement Filter

C Pressure Relief Valve

D Replacement Compressor

E Cooling Fan



F Cooling Fan Guard

G Compressor Fan Guard

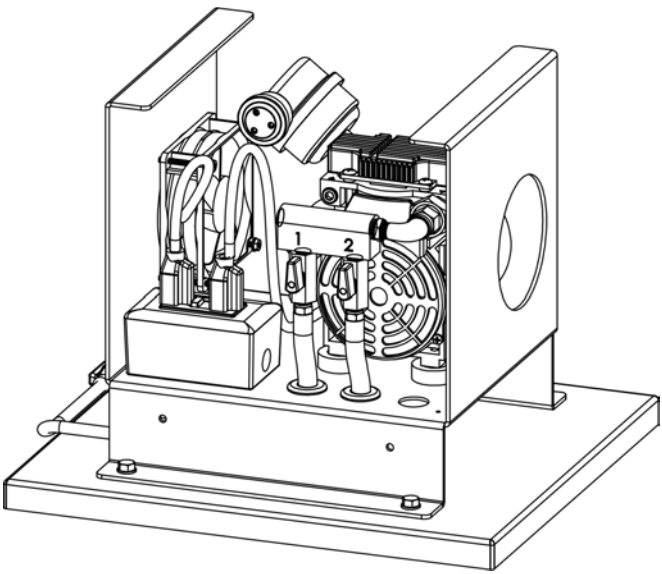
H Capacitor 230v

I Compressor Fan

J Solenoid Valve

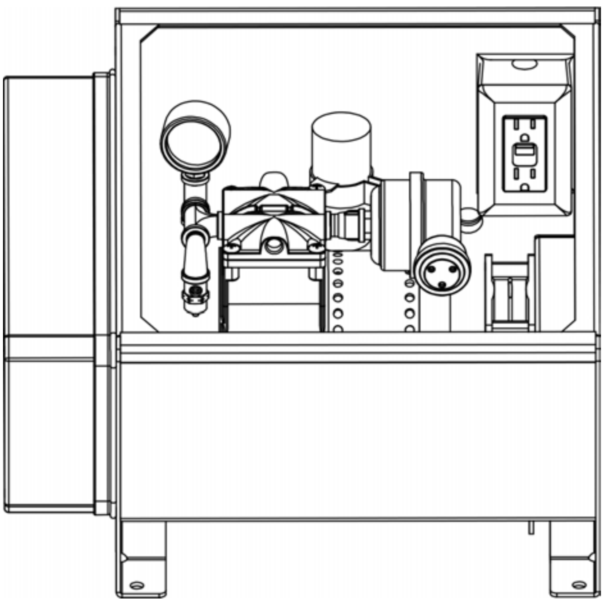
K Check Valve

Pondlyfe Cabinet ¼ hp 115 volt 60Hz				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	VAL433Z	Pressure Relief Valve	1	$16.00
	COM500-MK	Rebuild Kit	1	$104.00
D	COM500-CK	Replacement Compressor	1	$518.00
E	FAN117	Cooling Fan 115v	1	$59.00
F	FAN113Z	Cooling Fan Guard	1	$9.00
G	COM419Z	Compressor Fan Guard	1	$19.00
H	COM054Z	Capacitor 115v	1	$20.00
I	COM055Z	Compressor Fan - Black	1	$20.00



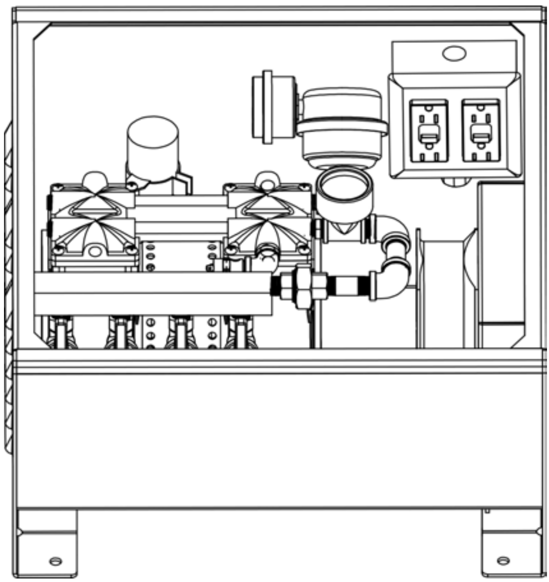
BriteStar Solar 24V BLDC 7 running amps				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	SUN300Z	Pressure Relief Valve	1	$16.00
E	FAN125Z	Cooling Fan	1	$39.00
F	FAN112Z	Cooling Fan Guard	1	$6.00
G	COM052Z	Compressor Fan Guard	1	$13.00
I	COM055Z	Compressor Fan - Black	1	$20.00
Replacement Compressor		**Call the Vertex Service Department for correct Part # and Price for these parts**		
Rebuild Kit				
Driver Board				

Small Cabinet 1/3 hp 115 volt 60 Hz				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT900Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	VAL435Z	Pressure Relief Valve	1	$16.00
	COM401-MK	Before 8/13 Brookwood Rebuild Kit	1	$63.00
	COM404-MK	Brookwood Rebuild Kit	1	$63.00
D	COM404-CK	Replacement Compressor	1	$568.00
E	FAN118	Cooling Fan 115v	1	$39.00
F	FAN113Z	Cooling Fan Guard	1	$9.00
G	COM419Z	Compressor Fan Guard	1	$19.00
H	COM131Z	Capacitor 115v	1	$26.00
I	COM415Z	Compressor Fan-Grey	1	$11.00



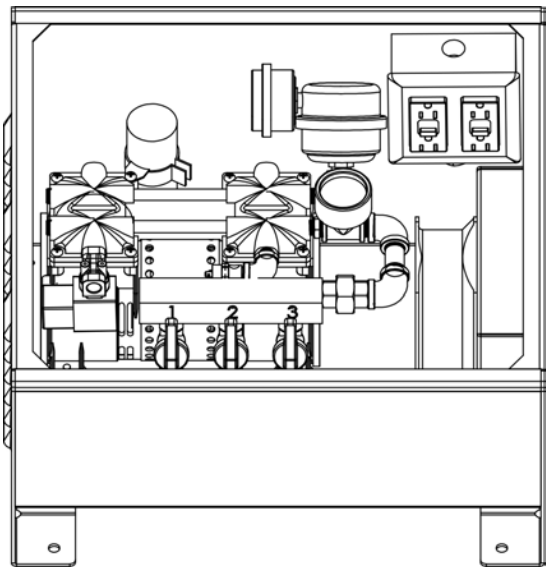
Small Cabinet 1/3 hp 230 volt 50-60 Hz				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT900Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	VAL435Z	Pressure Relief Valve	1	$16.00
	COM402-MK	Brookwood Rebuild Kit	1	$63.00
D	COM402-CK	Replacement Compressor	1	$594.00
E	FAN119	Cooling Fan 230v	1	$40.00
F	FAN113Z	Cooling Fan Guard	1	$9.00
G	COM419Z	Compressor Fan Guard	1	$19.00
H	COM140Z	Capacitor 230v	1	$18.00
I	COM415Z	Compressor Fan-Grey	1	$11.00

Medium Cabinet ½ hp 115 volt 60 Hz				
ID	Part #	Description	Qty.	Price
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	VAL435Z	Pressure Relief Valve	1	$16.00
	COM106-MK	Brookwood Rebuild Kit	1	$105.00
D	COM106-CK	Replacement Compressor	1	$655.00
E	FAN104	Cooling Fan 115v	1	$101.00
F	FAN114Z	Cooling Fan Guard	1	$11.00
G	COM412Z	Capacitor 115v	1	$20.00
H	COM415Z	Compressor Fan-Grey	1	$11.00
I	COM416Z	Compressor Fan-Black	1	$11.00
I	COM419Z	Compressor Fan Guard	2	$19.00



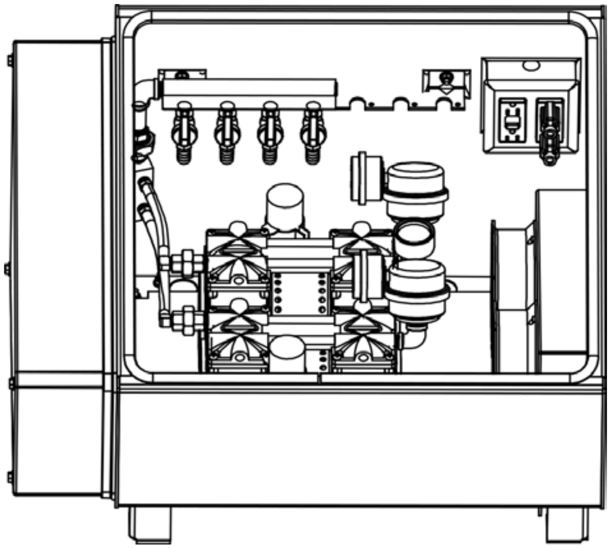
Medium Cabinet ½ hp 230 volt 50-60 Hz				
ID	Part #	Description	Qty.	Price
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	VAL435Z	Pressure Relief Valve	1	$16.00
	COM405-MK	Brookwood Rebuild Kit	1	$105.00
D	COM405-CK	Replacement Compressor	1	$665.00
E	FAN111	Cooling Fan 230v	1	$129.00
F	FAN114Z	Cooling Fan Guard	1	$11.00
G	COM409Z	Capacitor 230v	1	$17.00
H	COM415Z	Compressor Fan-Grey	1	$11.00
I	COM416Z	Compressor Fan-Black	1	$11.00
I	COM419Z	Compressor Fan Guard	2	$19.00

Medium Cabinet ¾ hp 115 volt 60 Hz				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	VAL434Z	Pressure Relief Valve	1	$16.00
	COM103-MK	Brookwood Rebuild Kit	1	$105.00
D	COM103-CK	Replacement Compressor	1	$667.00
E	FAN104	Cooling Fan 115v	1	$101.00
F	FAN114Z	Cooling Fan Guard	1	$11.00
G	COM419Z	Compressor Fan Guard	2	$19.00
H	COM412Z	Capacitor 115v	1	$20.00
I	COM415Z	Compressor Fan-Grey	1	$11.00
I	COM416Z	Compressor Fan-Black	1	$11.00
J	VAL312	Solenoid Valve	1	$106.00
K	VAL420Z	Check Valve – 1 per valve from cabinet		$17.00



Medium Cabinet ¾ hp 230 volt 50-60 Hz				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	1	$9.00
C	VAL434Z	Pressure Relief Valve	1	$16.00
	COM403-MK	Brookwood Rebuild Kit	1	$105.00
D	COM403-CK	Replacement Compressor	1	$672.00
E	FAN111	Cooling Fan 230v	1	$129.00
F	FAN114Z	Cooling Fan Guard	1	$11.00
G	COM419Z	Compressor Fan Guard	2	$19.00
H	COM409Z	Capacitor 230v	1	$17.00
I	COM415Z	Compressor Fan-Grey	1	$11.00
I	COM416Z	Compressor Fan-Black	1	$11.00
J	VAL312	Solenoid Valve	1	$106.00
K	VAL420Z	Check Valve – 1 per valve from cabinet		$17.00

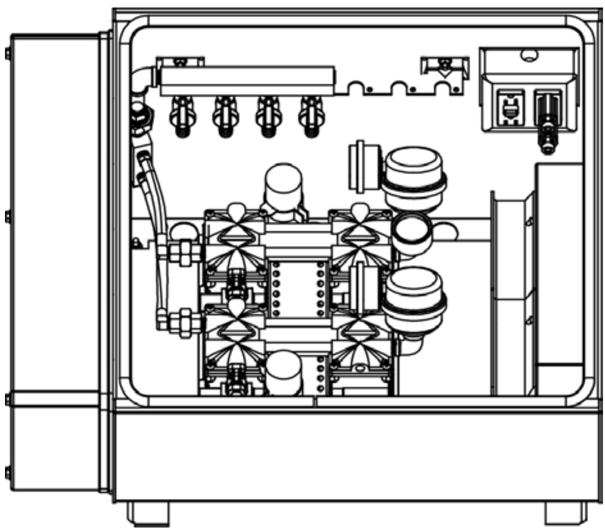
Large Cabinet 1 hp 115 volt 60 Hz				
ID	Part #	Description	Qty.	Price
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	2	$9.00
C	VAL435Z	Pressure Relief Valve	1	$16.00
	COM106-MK	Brookwood Rebuild Kit	2	$105.00
D	COM106-CK	Replacement Compressor	2	$655.00
E	FAN104	Cooling Fan 115v	2	$101.00
F	FAN114Z	Cooling Fan Guard	2	$11.00
G	COM419Z	Compressor Fan Guard	4	$19.00
H	COM412Z	Capacitor 115v	2	$20.00
I	COM415Z	Compressor Fan-Grey	2	$11.00
I	COM416Z	Compressor Fan-Black	2	$11.00



Large Cabinet 1 hp 230 volt 50-60 Hz				
ID	Part #	Description	Qty.	Price
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	2	$9.00
C	VAL435Z	Pressure Relief Valve	1	$16.00
	COM405-MK	Brookwood Rebuild Kit	2	$105.00
D	COM405-CK	Replacement Compressor	2	$665.00
E	FAN111	Cooling Fan 230v	2	$129.00
F	FAN114Z	Cooling Fan Guard	2	$11.00
G	COM419Z	Compressor Fan Guard	4	$19.00
H	COM409Z	Capacitor 230v	2	$17.00
I	COM415Z	Compressor Fan-Grey	2	$11.00
I	COM416Z	Compressor Fan-Black	2	$11.00

Large Cabinet 1 ½ hp 115 volt 60 Hz

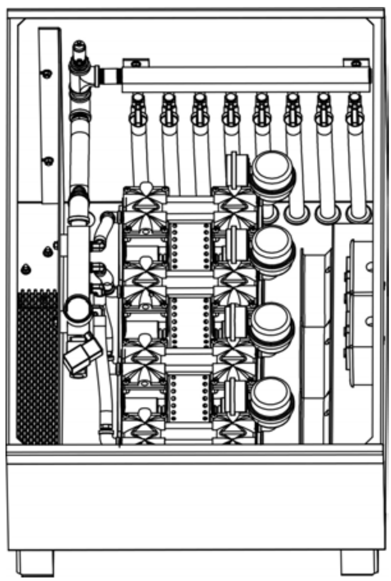
ID	Part#	Description	Qty.	Price
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	2	$9.00
C	VAL434Z	Pressure Relief Valve	1	$16.00
	COM103-MK	Brookwood Rebuild Kit	2	$105.00
D	COM103-CK	Replacement Compressor	2	$667.00
E	FAN104	Cooling Fan 115v	2	$101.00
F	FAN114Z	Cooling Fan Guard	2	$11.00
G	COM419Z	Compressor Fan Guard	4	$19.00
H	COM412Z	Capacitor 115v	2	$20.00
I	COM415Z	Compressor Fan-Grey	2	$11.00
I	COM416Z	Compressor Fan-Black	2	$11.00
J	VAL312	Solenoid Valve	1	$106.00
K	VAL420Z	Check Valve – 1 per valve from cabinet		$17.00



Large Cabinet 1 ½ hp 230 volt 50-60 Hz

ID	Part #	Description	Qty.	Price
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	2	$9.00
C	VAL434Z	Pressure Relief Valve	1	$16.00
	COM403-MK	Brookwood Rebuild Kit	2	$105.00
D	COM403-CK	Replacement Compressor	2	$672.00
E	FAN111	Cooling Fan 230v	2	$129.00
F	FAN114Z	Cooling Fan Guard	2	$11.00
G	COM419Z	Compressor Fan Guard	4	$19.00
H	COM409Z	Capacitor 230v	2	$17.00
I	COM415Z	Compressor Fan-Grey	2	$11.00
I	COM416Z	Compressor Fan-Black	2	$11.00
J	VAL312	Solenoid Valve	1	$106.00
K	VAL420Z	Check Valve – 1 per valve from cabinet		$17.00

Large Lake Cabinet 3 hp 230 volt 50-60 Hz				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	4	$9.00
C	VAL436Z	Pressure Relief Valve	1	$28.00
	COM403-MK	Brookwood Rebuild Kit	4	$105.00
D	COM403-CK	Replacement Compressor	4	$672.00
E	FAN111	Cooling Fan 230v	3	$129.00
F	FAN114Z	Cooling Fan Guard	3	$11.00
G	COM419Z	Compressor Fan Guard	8	$19.00
H	COM409Z	Capacitor	4	$17.00
I	COM416Z	Compressor Fan - Black	4	$11.00
I	COM415Z	Compressor Fan - Grey	4	$11.00
J	VAL414	Solenoid Valve	1	$173.00
K	VAL420Z	Check Valve – 1 per valve from cabinet		$17.00



LL HE33 Cabinet 4 hp 230 volt 50-60 Hz				
ID	**Part #**	**Description**	**Qty.**	**Price**
A	FIT888Z	Liquid Filled Pressure Gauge	1	$22.00
B	MUF202Z	Replacement Filter	4	$9.00
C	VAL437Z	Pressure Relief Valve	1	$27.00
	COM407-MK	Brookwood Rebuild Kit	4	$238.00
D	COM407-CK	Replacement Compressor	4	$1043.00
E	FAN107	Cooling Fan 230v	3	$177.00
F	FAN116Z	Cooling Fan Guard	3	$9.00
G	COM430Z	Compressor Fan Guard	8	$20.00
H	COM409Z	Capacitor	4	$17.00
I	COM432Z	Compressor Fan - Black	4	$16.00
I	COM431Z	Compressor Fan - White	4	$16.00
J	VAL414	Solenoid Valve	1	$173.00
K	VAL421Z	Check Valve – 1 per valve from cabinet		$18.00

Upper Red Rock Lake, MT:

Preliminary Engineering and Feasibility Analysis to Improve Winter Habitat for Arctic Grayling

Alternative 1 - Splasher Aeration Estimate

Material Estimates	Quantity	Unit Cost ($)	Cost ($)	Source or Assumption
Electrical service (installed)	1	$ 85,000	$ 85,000	Vigilante Electric (personal communication)
Floating splashers – 3 @ 1 HP	3	$ 1,200	$ 3,600	https://www.amazon.com/Kasco-Marine-Icer-Cycle-Deicer/dp/B076CBB8Y4; https://www.scottaerator.com/floating-pond-deicer
0/1 AWG submersible wiring (3 runs at maximum length of 4730 ft)	14,190	$ 9	$ 130,122	https://www.wireandcableyourway.com/submersible-pump-cable/
Installation (labor)	112	$ 160	$ 17,920	Contract labor at $160/hr (4 man crew for construction installation); Electrical (2 man crew) $160/hr
Equipment | ODCs	1	$ 9,652	$ 9,652	
Contingency (10%)			$ 23,664	
Total			**$ 269,959**	

Labor Estimates	Hours	Hourly Rate ($)	Cost ($)	Assumption
Anchor splashers to bottom	40	$ 160	$ 6,400	2 days travel, 3 days installation
Run wire	40	$ 160	$ 6,400	2 days travel, 3 days installation
Tie in electrical	32	$ 160	$ 5,120	2 days travel, 2 days installation
Labor Total			$ 17,920	

Equipment | ODCs	Days	Daily Rate ($)	Cost ($)	Assumption
Boat Rental	10	$ 250	$ 2,500	
Per diem	48	$ 149	$ 7,152	https://www.federalpay.org/perdiem/2019/montana
Other			$ -	
Equipment | ODC Ttotal			$ 9,652	

Upper Red Rock Lake, MT:

Preliminary Engineering and Feasibility Analysis to Improve Winter Habitat for Arctic Grayling

Alternative 1 - Wind Aeration Estimate

Material Estimates	Quantity	Unit Cost ($)	Cost ($)	Source or Assumption
39032 Koenders 18' Unipole SD Windmill System	31	$ 5,478	$ 169,818	Vedor quote (Koenders)
Drive Pilings	31	$ 1,500	$ 46,500	12" concrete @ 30 ft
Installation (labor)	128	$ 160	$ 20,480	Contract labor at $160/hr (4 man crew for construction installation)
Equipment | ODCs	1	$ 39,132	$ 39,132	
Contingency (10%)			$ 23,680	
Total			**$ 299,610**	

Labor Estimates	Hours	Hourly Rate ($)	Cost ($)	Assumption
Installation	128	$ 160	$ 20,480	2 days travel, 14 days installation
			$ -	
			$ -	
			$ 20,480	

Equipment | ODCs	Days	Daily Rate ($)	Cost ($)	Assumption
Boat Rental	16	$ 250	$ 4,000	
Per diem	68	$ 149	$ 10,132	https://www.federalpay.org/perdiem/2019/montana
Mobilization	1	$ 25,000	$ 25,000	
Equipment | ODC Ttotal			$ 39,132	

Parker, Winston S.

From: Spencer Cota <scota@koenderswatersolutions.com>
Sent: Tuesday, April 09, 2019 9:43 AM
To: Parker, Winston S.
Subject: Quote: Windmill Aeration System (Uni Pole Tower)***this is just a quote

KOENDERS WATER SOLUTIONS, INC. Nature's POND

Thank you for your order! Click below for payment options.

Hello,

-this is just a quote, please disregard where it says thank you for your order.

Please view the below quote as per our conversation today.

More info at www.koenderswatersolutions.com

Spencer Cota

Pond Care Consultant

Phone: EXT 3, toll free 1-877-888-7707

Click here to complete your purchase

Order summary

Accessories × 20 — **$1,499.00**
10110 3/8" Weighted Air Line - 50' roll

Accessories × 20 — **$99.00**
30044 3/8" Hose Connector & Clamp Pack

	**Windmill Systems × 1** 39032 Koenders 18' Unipole SD Windmill System - includes: 18' Unipole Tower Box with Tail Arms, Single Diaphragm Compressor, 24" Blade & Tail Box, Airstone, Foot Valve & 100' 3/8" Airline	**$2,099.00**
	**Powder Coating - Ships from Canada × 1** 10327 24' Grass Green	**$1,095.00**
	**Freeze Kit Parts × 1** 20130 Pressure Release Valve	**$49.95**
	**Accessories × 1** 20728 "J" Anchor Bolt Set (4) for Unipole Foundation	**$149.95**

Subtotal	**$4,991.90**
Shipping	**$486.39**
Total	**$5,478.29 USD**

Customer information

Shipping address

Winston Parker

Lake View, Montana

Billing address

Winston Parker

Upper Red Rock Lake, MT:

Preliminary Engineering and Feasibility Analysis to Improve Winter Habitat for Arctic Grayling

Alternative 1 - Solar Aeration Estimate

Material Estimates	Quantity	Unit Cost ($)	Cost ($)	Source or Assumption
SB10000LH v20 SolarBee Mixer	3	43,760	$ 131,280	Vedor quote (Medora)
Installation (labor)	1	14,019	$ 14,019	Vedor quote (Medora)
Equipment | ODCs	0	-	$ -	
Contingency (10%)			$ -	
Total			**$ 145,299**	

Labor Estimates	Hours	Hourly Rate ($)	Cost ($)	Assumption
Installation	1	$ 14,019	$ 14,019	Vedor quote (Medora)
			$ -	
			$ -	
			$ 14,019	

Equipment | ODCs	Days	Daily Rate ($)	Cost ($)	Assumption
Boat Rental			$ -	
Per diem			$ -	
Other			$ -	
Equipment | ODC Ttotal			$ -	

MEDORA corporation

Main Office & Service Center
1-866-437-8076 | medoraco.com
3225 Highway 22, Dickinson, ND 58601

Quotation: Reservoir Circulation Equipment for Upper Red Rocks Lake

Date: March 27, 2019

Project #: 11397

To: Winston Parker
CDM Smith
parkerws@cdmsmith.com • 406-441-1447

From: Craig Steve, Medora Corporation Regional Manager, Dickinson, ND
craig.steve@medoraco.com • 701-227-5397

Eric Ridl, Medora Corporation Engineered Sales Dept., Dickinson, ND
eric.ridl@medoraco.com • 866-437-8076

1. Reservoir Name, Location, Description and Primary Problems

Upper Red Rock Lake is located 4 miles west of Lakeview, MT (GPS: 44.608683°, -111.722436°). It is approximately 2,207 acres with a max depth of 6'. The lake has issues with low DO in the winter which affects the population of Arctic Grayling.

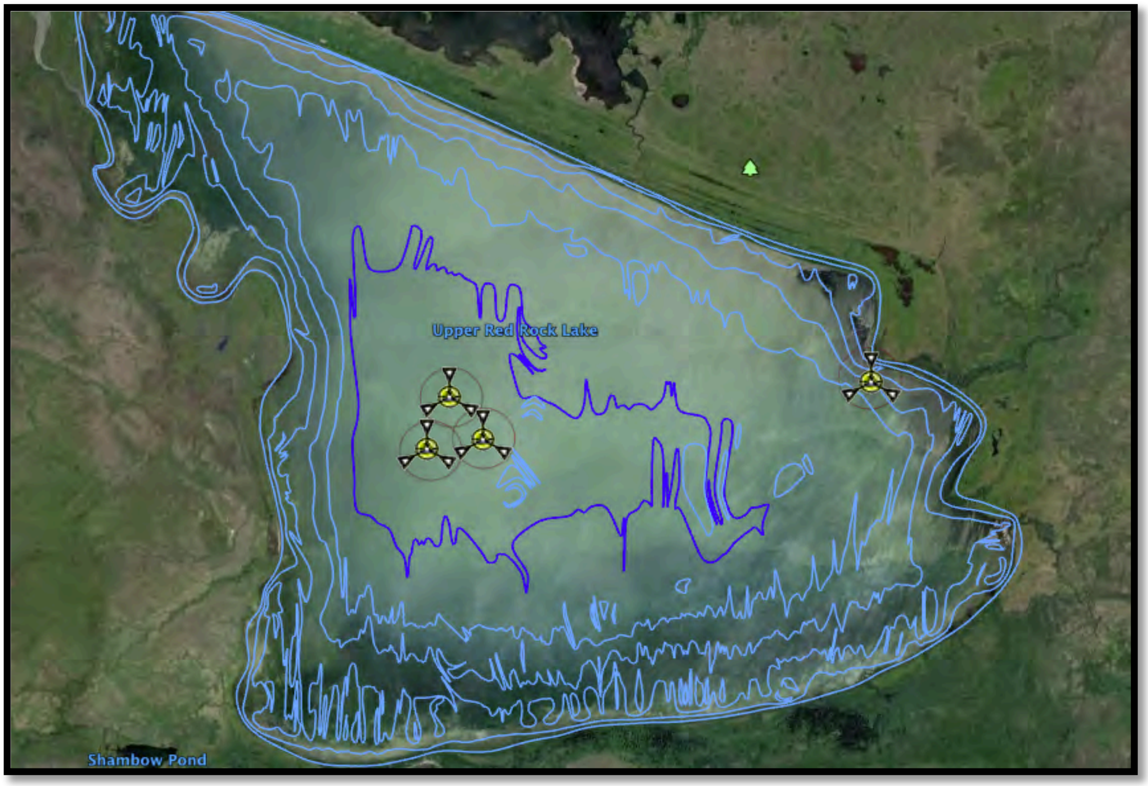
2. Customer Objectives

To provide long-distance circulation to improve a 62 acre fish habitat in the middle of Upper Red Rock Lake. An optional objective to create a firmer lake bottom near the spawning creek is added in the design below.

3. Medora Corporation Recommendation / System Design for this Project

To meet the above objectives we recommend the placement of four (4) SB10000LH v20 machine set for 20 acre spacing. Options for an incremental approach with fewer machines are included in the pricing tables below.

4. Proposed Machine Placement



The machines are not drawn to scale, and final placement will be determined prior to deployment.

5. Equipment Cost

Pricing for four (4) Solar-Powered Machines:

Quantity	Equipment Description	Cost Each	Equipment Total
4	SB10000LH v20 SolarBee Mixer: Including intake plate, High torque, direct drive (no gearbox), low voltage brushless D.C. motor, mooring kit and SCADA brain-board with six outputs.	$43,760	$175,040
		Equipment Subtotal:	$175,040
		Applicable Taxes:	-to be determined -
		Discounted Factory Delivery, Placement and Startup:	$17,593
		Equipment, Factory Delivery, Placement and Startup Total:	$192,633

12-Month Rental (See Rental Provisions Below for Details)	
Monthly cost for recommended machines per above:	$4,586
Monthly Beekeeper cost during the term of the rental:	$560
*Factory Delivery, Placement and Startup:	$17,593
Total 12-Month Rental Cost:	$79,345

*When the rental period is over, if the customer does not wish to purchase or continue the rental and has paid the placement cost, then Medora pays the retrieval cost.

Pricing for three (3) Solar-Powered Machines:

Quantity	Equipment Description	Cost Each	Equipment Total
3	SB10000LH v20 SolarBee Mixer: Including intake plate, High torque, direct drive (no gearbox), low voltage brushless D.C. motor, mooring kit and SCADA brain-board with six outputs.	$43,760	$131,280
		Equipment Subtotal:	$131,280
		Applicable Taxes:	-to be determined -
		Discounted Factory Delivery, Placement and Startup:	$14,019
		Equipment, Factory Delivery, Placement and Startup Total:	$145,299

12-Month Rental (See Rental Provisions Below for Details)	
Monthly cost for recommended machines per above:	$3,439
Monthly Beekeeper cost during the term of the rental:	$420
*Factory Delivery, Placement and Startup:	$14,019
Total 12-Month Rental Cost:	$60,327

*When the rental period is over, if the customer does not wish to purchase or continue the rental and has paid the placement cost, then Medora pays the retrieval cost.

Pricing for two (2) Solar-Powered Machines:

Quantity	Equipment Description	Cost Each	Equipment Total
2	SB10000LH v20 SolarBee Mixer: Including intake plate, High torque, direct drive (no gearbox), low voltage brushless D.C. motor, mooring kit and SCADA brain-board with six outputs.	$43,760	$87,520
		Equipment Subtotal:	$87,520
		Applicable Taxes:	-to be determined -
		Discounted Factory Delivery, Placement and Startup:	$9,896
		Equipment, Factory Delivery, Placement and Startup Total:	$97,416

12-Month Rental (See Rental Provisions Below for Details)	
Monthly cost for recommended machines per above:	$2,293
Monthly Beekeeper cost during the term of the rental:	$280
*Factory Delivery, Placement and Startup:	$9,896
Total 12-Month Rental Cost:	$40,772

*When the rental period is over, if the customer does not wish to purchase or continue the rental and has paid the placement cost, then Medora pays the retrieval cost.

Pricing for one (1) Solar-Powered Machines:

Quantity	Equipment Description	Cost Each	Equipment Total
1	SB10000LH v20 SolarBee Mixer: Including intake plate, High torque, direct drive (no gearbox), low voltage brushless D.C. motor, mooring kit and SCADA brain-board with six outputs.	$43,760	$43,760
		Equipment Subtotal:	$43,760
		Applicable Taxes:	-to be determined -
		Factory Delivery, Placement and Startup:	$5,498
		Equipment, Factory Delivery, Placement and Startup Total:	$49,258

12-Month Rental (See Rental Provisions Below for Details)	
Monthly cost for recommended machines per above:	$1,146
Monthly Beekeeper cost during the term of the rental:	$140
*Factory Delivery, Placement and Startup:	$5,498
Total 12-Month Rental Cost:	$20,930

*When the rental period is over, if the customer does not wish to purchase or continue the rental and has paid the placement cost, then Medora pays the retrieval cost.

Options for Solar Models	
SCADA Outputs	All SB v20 and reconditioned models come standard with a SCADA brain-board with six outputs. All GF models come standard with a SCADA brain-board with four outputs. For additional SCADA Accessories please request a price sheet.
Beekeeper Service Program	The BeeKeeper ensures GridBee and SolarBee equipment is well maintained and operating at peak performance thus achieving the best possible water quality. The BeeKeeper allows our customers to take full advantage of Universal Damage Repair, System Upgrades, Annual Onsite Maintenance and more. Details of the Beekeeper Service Program are available at: https://www.medoraco.com/beekeeper

6. General Provisions

A. Material Supplier only. This quotation is to supply materials only. No contracting or construction work of any type is being offered or will be performed by Medora Corporation (Medora) at the jobsite or at any Medora location or factory.

1) To order the materials in this quotation, the purchaser should use the same type of purchase order as would be used to order other materials; for example, a desk or a forklift. Please do not attempt to order the equipment quoted here with a "contractor" or "subcontractor" agreement of any sort, because Medora is strictly a material supplier, not a contractor, and would have to reject that type of agreement.

2) The US Department of Labor clearly defines a Material Supplier, such as Medora, and its allowable activities. All activities by Medora factory personnel to transport, place and start up the Medora equipment are incidental to Medora being a Material Supplier, and Medora will not perform contracting or construction work of any type for any project. Also, no local, state, or federal laws regarding contractors or construction projects, or Davis Bacon or similar reporting requirements, are applicable to this quotation because Medora is not a contractor and does not perform any construction activities.

3) It is the responsibility of the purchaser of Medora's equipment to determine in advance whether there are any contracting or construction activities required in order for Medora's equipment to be made operational. Usually there aren't any such activities; but if there are, it is the purchaser's sole responsibility, at its sole cost, to perform all of those activities in advance of Medora's equipment arriving at the jobsite.

B. Assumptions: This quotation may be based on worksheets, calculations or other information that has been provided by the City. The City should bring to Medora's attention any discrepancies, errors in data, or false assumption that Medora may have made while preparing this quotation.

C. Expiration: This quotation expires in 90 days, or on the date of any new quotation for this project, whichever is sooner.

D. Delivery Time: Delivery, Placement, and Startup is scheduled at time of order, and is usually between 4 and 8 weeks.

E. Payment Terms: For a federal, state, or local government purchaser with a good credit rating, full payment is due in US dollars 30 days after invoice date, which is generally the date when the goods leave the Medora factory. For a non-government purchaser, full payment must be made by credit card or cashier's check before the goods leave the Medora factory though, in some cases, based on availability of a payment bonding or a bank Letter of Credit, 30 day credit terms may be extended upon special request by the purchaser. If there are any issues with these payment terms, please do not rely on this quotation until the issues have been resolved

F. Add for Taxes and Any Governmental Fees: Except as indicated above, no taxes, tariffs or other governmental fees are included in the quote shown above, nor are there any costs added for special insurance coverage the customer may require. It is the customer's responsibility to pay all local, state, and federal taxes, including, sales and use taxes, business privilege taxes, and fees of all types relating to this sale, whether they are imposed on either Medora or the customer, or whether these taxes and fees are learned about after the customer orders the equipment. The customer's purchase order should indicate any taxes or fees due on equipment and/or services, and whether the customer will pay them directly to the governing body or include the tax payment with the purchase for Medora to submit them to the governing body.

G. Add for Special Insurance Requirements: Medora Corporation maintains adequate liability and workman's compensation insurance to generally comply with its requirements for doing business in all fifty U.S. states, and will provide at no charge certificates of insurance when requested. However, if additional insurance or endorsements beyond the company's standard policy are required by the customer, then the costs of those additional provisions and/or endorsements will be invoiced to the customer after the costs become known.

H. Add for Special Training, Safety, Signage, or Other Requirements: Medora has a very strong safety training program for its employees. If any special training classes for Medora personnel are required by the customer, please notify Medora well in advance. The cost of this training will be added to this quotation or invoiced to the customer separately. The same applies to any other special requirements the customer may have, including providing of project signage or any other requirement.

I. Safe and Accessible Working Conditions Required. This quotation is based on the best information made available to us by the above date. If this equipment is ordered, Medora's engineering team will need detailed information and photographs to plan the equipment placement. If the detail information changes the scope significantly, Medora reserves the right to withdraw or alter this quotation, even if the equipment has already been ordered. To avoid surprises, the City should supply detailed information and photos as soon as possible.

J. Customer to Follow Medora's Maintenance and Safety Guidelines: The customer agrees to follow proper maintenance, operating, and safety instructions regarding the equipment as contained in the safety manual that accompanies the equipment or is sent to the customer's address.

K. Regulatory Compliance. The customer must comply with all applicable Federal and State governmental regulations. It is the customer's sole responsibility to inquire about governmental regulations and ensure that GridBee and SolarBee equipment is deployed and maintained so as to remain in compliance with these regulations and guidelines, and to hold Medora harmless from any liability caused by non-compliance with these regulations and guidelines.

L. Warranty. Medora Corporation has the best parts and labor warranties that we are aware of in the industry. The details of the Warranty which applies to this project are either attached to this document or are available at: https://www.medoraco.com/resources/warranty-information.

M. Medora Corporation's Rental Provisions:

Rental Payment Terms: The placement day of the month is the anniversary day for determining when a new rental month begins. There are no partial months; if the equipment is in place on the first day of the rental month, a whole month of rental is due. Rental invoices will be provided each month and payment is due 30 days from the invoice date. The delivery, placement, and startup charge mentioned above will be added to the first month's rental invoice.

Rental Period, Month-to-Month: The rental period shall be for one month, beginning on the placement date, and shall continue automatically, for one month at a time beginning on each monthly anniversary of the placement date, until the longer of (a) 12 months for Solar mixers or (b) 90 days after written notice is received by Medora Corporation from the renter to terminate the rental. Furthermore, Medora Corporation has the right to terminate the rental agreement and re-possess the equipment at any time, without notice to the renter, if the renter becomes delinquent in rent payments.

Periodic Rental Cost Adjustment: The rental cost may be adjusted periodically by Medora Corporation upon 90 day written advance notice to the renter, after the minimum rental period mentioned above. Medora Corporation expects, but does not promise, to make such adjustments only once per year on the anniversary date of the placement, and expects that adjustments will be limited to reflect (a) a general inflationary adjustment equal to the Consumer Price Index, and (b) any additional costs by the factory associated with keeping the rental equipment functioning properly and meeting the renter's goals for the project. The renter, at its option as mentioned above, may cancel the rental agreement with 90 day notice if the proposed new rental costs are ever not acceptable.

Rental Conversion to Purchase: The renter may convert this rental to a purchase at the price shown in the Equipment Purchase section above. At least 60 days before the desired purchase date (30 days for GridBee AP units), the renter should request from Medora Corp. a firm quotation for converting the rental to a purchase. When conversion to a purchase is made, 100% of the delivery, placement, and startup is applied to the purchase price, plus 50% of prior equipment rents paid, up to a maximum of 50% of the equipment purchase price. Title to the rental equipment does not pass to the renter unless and until payment of all outstanding rental invoices, and the conversion purchase price for the equipment, is received by the Medora

Rental Equipment Availability: Medora Corporation has a limited supply of rental machines available; either new or slightly used or "demonstrator" equipment may be placed at the factory's option. If the equipment placed for a rental is slightly used, then the factory warrants that: (1) the equipment is clean, current, and in like-new condition with a full new-equipment warranty, and (2) the equipment is equivalent to new equipment with the very latest technology and improvements. Also note that SCADA or other remote monitoring options may have been included in the purchase cost in Section 2 above, but these components are not included with rental equipment. If a rental is desired, the SCADA remote monitoring equipment would be placed only after the equipment had been converted to a purchase, unless other provisions have been made.

Maintenance of the Equipment: Renter is to provide minor routine care and maintenance of the Equipment as described in the owners manual. The Beekeeper Service Program is required and is included in the cost shown above for the term of the rental. Beekeeper terms can be found at https://www.medoraco.com/beekeeper.

7. To Accept This Quotation

To order the equipment, please issue a purchase order to Medora Corporation, 3225 Hwy. 22, Dickinson, ND 58601. The purchase order can be mailed to the address above, faxed to 866-662-5052, or emailed to the home office at orderprocessing@medoraco.com.

This Medora Corp. quotation should be attached to the purchase order, and the purchase order should refer to the Medora Corp. quotation by date, and should accept the quotation in its entirety. Acceptable language on the purchase order would be " Quantity: 1. Description: "Equipment per the attached quotation from Medora Corp dated _____________, including all terms shown on that quotation. " If there is any language missing, or extra language in the purchase order such as a referral to specifications, then Medora Corp. will not be able to accept the purchase order.

If a purchase orders is not utilized, please sign and date below, provide billing information, and fax to 866-662-5052 or email to orderprocessing@medoraco.com.

Signing below acknowledges acceptance of this quotation. Please indicate which of the following machine options you have chosen.

Proposal Date: March 27, 2019

Project #: 11397

Four (4) Machines	**Three (3) Machines**	**Two (2) Machines**	**One (1) Machine**
☐ Purchase	☐ Purchase	☐ Purchase	☐ Purchase
☐ Rental	☐ Rental	☐ Rental	☐ Rental

______________________________ Signature

______________________________ Date

______________________________ Printed Name

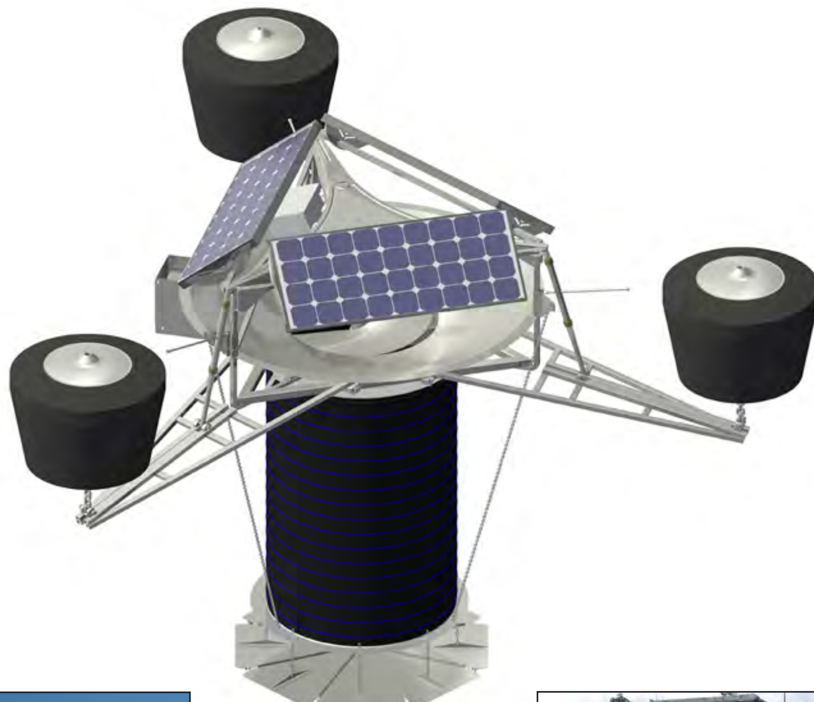
______________________________ Title

Medora Corporation

SolarBee®

Contents

SB10000LH OWNER'S MANUAL



Medora Corporation • 3225 Hwy 22 • Dickinson, ND 58601
Ph +1 701 225 4495 • +1 866 437 8076 • Fax +1 701 225 0002 • www.medoraco.com

937_20161206

Safety Instructions

IMPORTANT

YOU MUST COMPLETELY READ AND FULLY UNDERSTAND THESE INSTRUCTIONS BEFORE INSTALLING, OPERATING, OR SERVICING THIS UNIT.

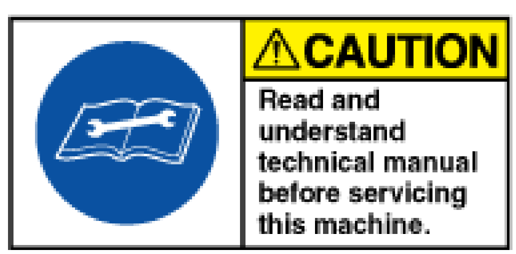
Be sure you have read all installation, operation, maintenance, and safety instructions before you install, service or begin to operate this unit.

Accidents occur every year because of careless use of industrial equipment. You can avoid hazards by following these safety instructions, and applying some ordinary common sense when operating or servicing this unit.

Keep in mind that **full operator attention and alertness** are required when operating or servicing this unit.

Use common sense! Most accidents can be avoided by using **common sense and concentrating** on the job being done.

Carefully read safety information when you see any safety symbols:



Safety

Crush Hazard

CAUTION: DO NOT REMOVE ANY FLOAT ARM OR TURNBUCKLE PINS OR BOLTS WHILE THE SOLARBEE IS FLOATING IN THE WATER! THE SOLARBEE MUST BE RESTING ON THE GROUND OR SAFELY SUPPORTED TO RELIEVE THE FORCES ON THE FLOAT ARM AND TURNBUCKLE STRUCTURES PRIOR TO DISASSEMBLY! FAILURE TO FOLLOW THIS WARNING COULD LEAD TO SINKING THE SOLARBEE, OR CAUSE SERIOUS INJURY!

Rotating Equipment

CAUTION: KEEP BODY APPENDAGES OR LOOSE CLOTHING AWAY FROM THE IMPELLER ASSEMBLY WHILE THE MACHINE IS OPERATING! IF MAINTENANCE IS REQUIRED, BE SURE TO TURN THE SOLARBEE OFF FIRST! WEAR PROTECTIVE GLOVES AND BE CAUTIOUS OF SHARP LEADING EDGES ON IMPELLER BLADES WHILE CLEANING! FAILURE TO FOLLOW THESE WARNINGS COULD LEAD TO INJURY!

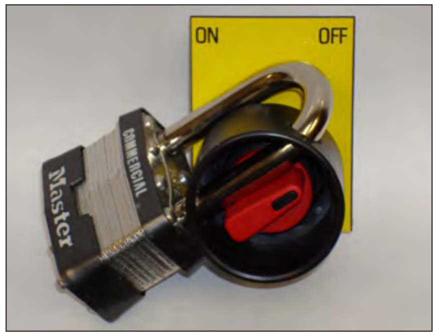
Entanglement Hazard

WARNING: IF MOVING OR DEPLOYING MOORING BLOCKS CONNECTED TO THE ANCHOR CHAIN, BE SURE THAT YOU AND OTHERS ARE CLEAR OF THE ANCHOR CHAIN BEFORE SINKING THE MOORING BLOCKS! LOWER THE MOORING BLOCKS INTO THE WATER SLOWLY. FAILURE TO DO SO COULD CAUSE SERIOUS INJURY OR DEATH BY DROWNING!

THIN ICE HAZARD

WARNING: DURING WINTER CONDITIONS WHEN THE SOLARBEE IS FROZEN IN OR PARTIALLY FROZEN IN, THE MACHINE SHOULD NOT BE APPROACHED. THE ICE AND SNOW AROUND THE SOLARBEE SHOULD NOT BE ASSUMED TO SUPPORT WEIGHT. FAILURE TO DO SO CAN RESULT IN SERIOUS INJURY OR DEATH BY DROWNING OR HYPOTHERMIA!!!

Lock Out - When the On/Off switch is in the On position, the SolarBee may start up at any time. The SolarBee On/Off switch can be locked out by placing a pad lock through the shroud of the switch while it is in the Off position. The On/Off switch is to be used as the emergency stop.



EU Declaration of Conformity
Trade Name: SolarBee
Responsible Party: Medora Corp.
Address: 3225 Hwy 22
Dickinson, ND 58601 USA
Telephone: 1-866-437-8076
This equipment complies with:

- Machinery Directive 98/37/EC
- Noise Emissions of Outdoor Equipment Directive 2004/14/EC
- Electromagnetic Compatibility Directive (EMC) 89/336/EEC

Signage and Instuctions - The SolarBee is supplied with warning signage and instructions written in the english language. It is very important that all operators and the public having access to the SolarBee equipment be informed of the associated safety hazards. If english is not the dominant language in the region, SolarBee strongly recommends that all warning signage and instructions be translated to the dominant language.

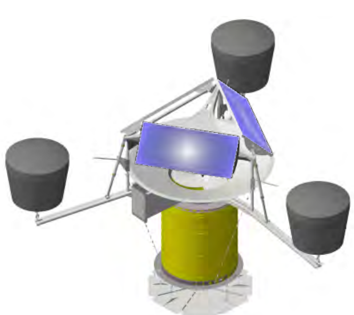
For SolarBee machines installed into a public reservoir where there is open access to the machine, it is strongly encouraged to properly notify the public of its presence. To avoid an injury or damage to the equipment, the public should remain at least 5 meters away from the machine at all times. Below is a sample public notification sign:

PUBLIC INFORMATION NOTICE

The City of _______ has installed SolarBee® solar-powered high-flow long-distance circulation equipment to improve the water quality and to enhance the recreational value of the lake.

Some facts about SolarBee SB10000HW v18 / 10000 gpm Circulators:

SolarBee®
Circulating the World's Water



- SolarBees come in various sizes, the largest unit circulates 14 million gallons per day. The machine in this lake circulates 14 million gallons per day.
- The machine runs during daylight & night hours entirely powered by solar energy.
- SolarBee long distance water circulation helps:
  - o prevent lake water stagnation,
  - o control blue-green algae blooms,
  - o improve the lake ecosystem,
  - o provide a healthy environment for fish, frogs, crayfish, and other aquatic organisms.
- SolarBee units have an expected life of 25+ years.
- More information on this technology is available at *www.solarbee.com*.

Help Us Keep the SolarBee Working.
Report vandalism, by calling the

____

For your safety, and to help achieve the water quality goals for this lake, please do not go near the machines.

Thank you for purchasing this **SolarBee** with the new ***Technology***.

We trust that you'll find the SolarBee to be very effective in treating your water. Every SolarBee is tested and inspected at our manufacturing facility before being delivered to you. An experienced and trained SolarBee field team will deliver and install your SolarBee. During the installation, the field team will present to you a summary of the background, operation, and routine maintenance of your SolarBee. They are very helpful and willing to answer any field questions you may have.

The SolarBee has proven to be effective in a variety of applications including wastewater, freshwater, potable water, stormwater, and salt water. Research and development continue to be a high priority in order to provide you with the up-to-date knowledge and best technology available for your application. Extensive design efforts have been made to make the SolarBee easy to maintain with high quality, long life parts.

If at any time you feel that your SolarBee is not operating at its full potential, feel free to contact the main office where a knowledgeable SolarBee service team is available to offer help. There are methods of field adjustment that may be beneficial following the installation. Our service team will gather the latest information on your application and combine it with their experience to optimize the performance of your SolarBee.

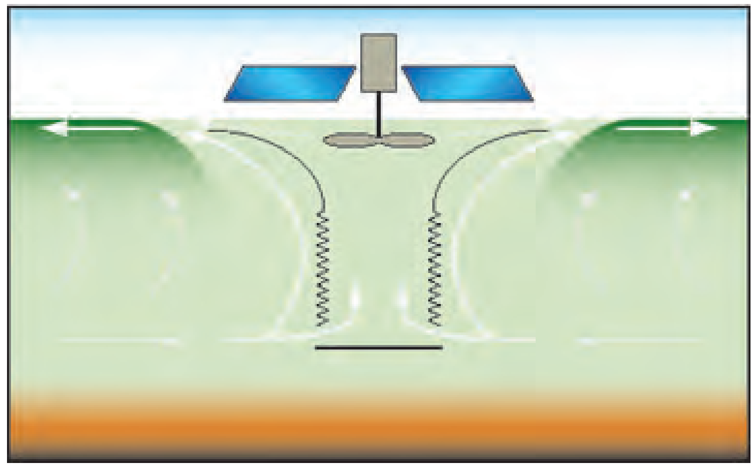
Technology Features

- *Solar power achieving day/night operation*
- *Durable brushless motor*
- *Advanced digital control system*
    - *Scheduled-reverse*
    - *Anti-jam routine*
    - *Seasonal RPM*
    - *SCADA outputs, machine monitoring*
    - *SD Card reprogrammable*
- *Robust frame and float arm structures*
- *Corrosion Resitant, 316 Stainless Steel*
- *Swinging PV module gates*
- *PV modules with angle adjustment*
- *Quick detachable impeller*
- *Low floating profile, improved aesthetics*
- *Smooth, quiet operation*

SolarBee Delivery Fleet

Operation

The SolarBee is designed to circulate water by bringing water from below and sending it out across the top in a thin layer causing a mixing effect. The laminar layer flows outward radially, in diverging "stream lines" from the distribution dish. As it does, vertical flow is induced in between the water being drawn below and the water above. At the level of the flow intake, water is drawn from all corners of the pond. As this lower layer of fluid makes its way inward with converging streamlines to the SolarBee, the water is forced upward, toward the surface, providing gentle mixing, de-stratification, and surface renewal.



SB10000HW Flow Pattern

The SolarBee obtains all the energy it needs from the sun. Its solar panels provide power to the onboard battery which energizes the drive system's controls and motor. The new Technology allows excess solar energy to be stored during the day and used during the night allowing the SolarBee to operate during the night without being connected to the grid.

Flow Coming Off Distributor Dish

During operation, a visible flow can be observed coming off the distributor dish and spreading outward. The impeller of the SolarBee is designed to operate at full speed when there is sufficient sunlight and battery charge. The rpms may drop down some during the later night and early morning when the battery uses up its charge after a longer period of overcast days. In severe sunlight limited conditions, the machine may slow down or stop temporarily to protect the battery from damage.

Features

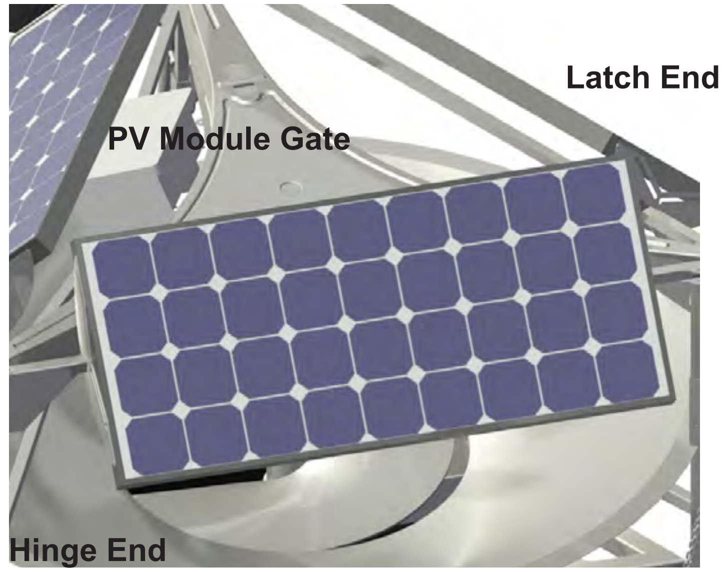
The SolarBee with technology includes new features which enhance its performance through more efficient and durable components, improved operation monitoring capablilities, easy component access, and a robust frame structure.

Solar / Electronics

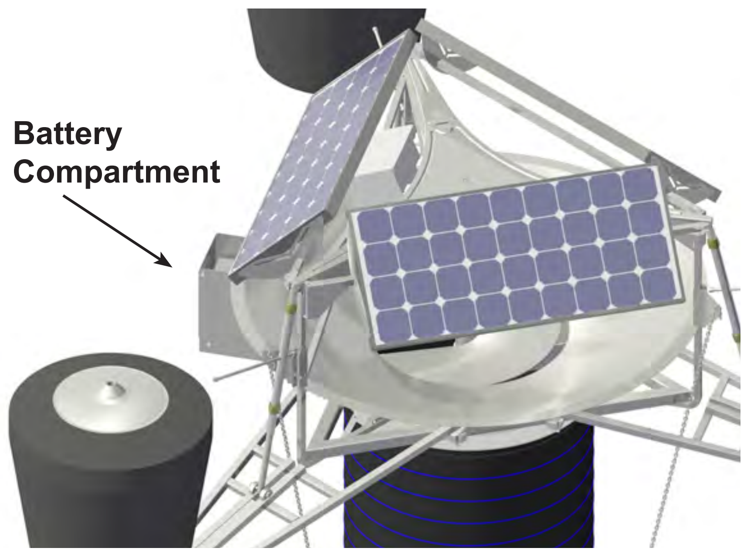
Photovoltaic (PV) Modules -The PV modules are often referred to as the solar panels. The SolarBee uses 100% solar energy to provide day/night operation. The PV modules collect solar power to operate the machine with excess left over to charge an onboard 12-volt, deep cycle battery. The SolarBee has 3 80-watt PV modules which individually connect to the digital controller. A bird deterrent is located directly above the PV modules to prevent bird fouling.

The PV modules have 3 angle settings that are set at the factory based on solar energy availability unique to the customer's geographic location. The flattest position is a 35 degree angle for customers located where solar power availability is greatest. The mid-range setting position is a 45 degree angle for customers where solar power availability is moderately available. The steepest position is a 55 degree angle intended for winter conditions to prevent snow and ice buildup from lasting a long time period on the PV modules (following winter conditions, the PV modules should be returned to their original position to maximize solar energy collection).

For cable tethered anchoring, the north facing panel may be flipped to face the south using a special panel gate. A tethered machine is fixed and will not rotate, so the north facing panel will receive the least sunlight, unless flipped using the special gate. For mooring block anchoring, this is not an option due to the machine rotating about the mooring blocks.



Each PV module is fixed to a gate that opens up allowing quick access to the interior components of the machine. Each gate opens by simply removing a pin on the latch end.

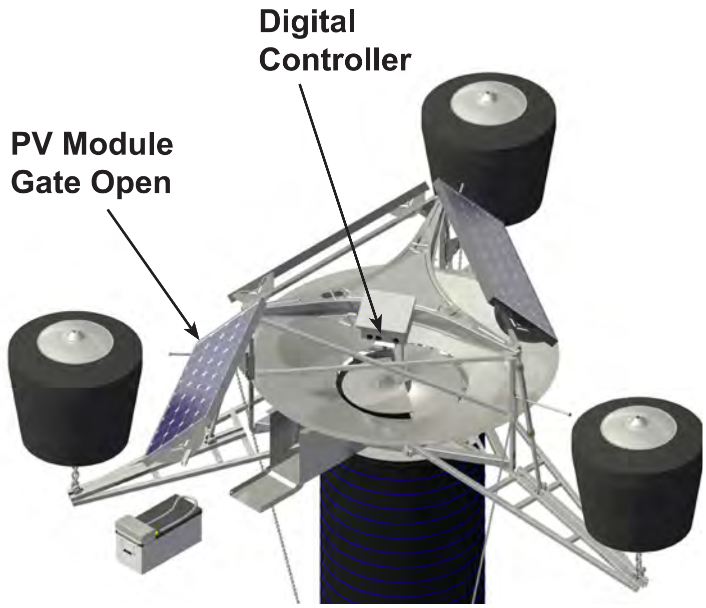


Onboard Battery - The onboard battery is located directly below the dish in a stainless steel compartment. During operation, the battery is submerged in the water to maintain a stable-temperature environment that increases its performance and life. The battery is double-walled to isolate its contents from the water it is submerged in.

The onboard battery stores excess power from the solar panels during the day and operates the machine using the stored power during the night and extremely overcast days.

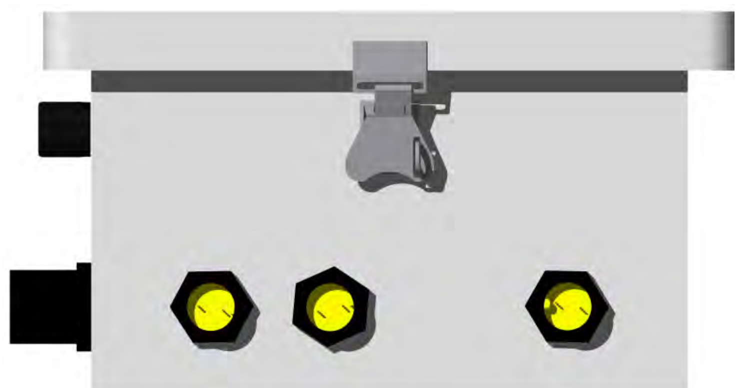
Onboard Battery

Digital Controller - The digital controller is located near the top center of the SolarBee. The digital controller can be easily accessed by opening the PV module gate directly above and in front of it. The digital controller is constructed with a NEMA 4X (IP 66) Enclosure.



All solar energy collection and motor operation are managed by the digital controller. This component has two primary functions: (1) To direct and divide the power being collected by the PV modules between the brushless motor and battery. (2) To serve as the main control center that operates the brushless motor.

There are 3 PV module connections located on the front face of the digital controller. If the onshore power accessory was purchase, a connection will be located on the right side face. The onshore connection is used only in applications where onshore grid power is desired.



Front Face Of Digital Controller

The left side face of the digital controller contains the brushless motor connection, battery connection, and On/Off switch. The On/Off switch activates power to the motor. When the switch is turned to the Off position, the motor will not operate. The charging function of the controller will continue to charge the battery even when the switch is turned off.

Left Side Face Of Digital Controller

SCADA outputs offering machine operation parameters reside within the digital controller. Please contact SolarBee if you are interested in receiving these parameters.

Motor Controller - The motor controller is located near the motor just below the top plate of the SolarBee. The motor controller is sealed in line with the electrical cord that runs to the brushless motor.

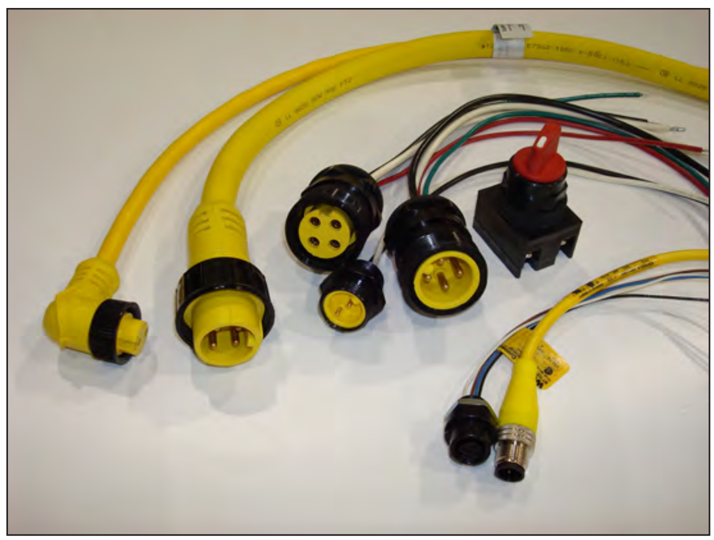
The motor controller on the SolarBee receives power and signals from the main control center located inside the external enlosure. These signals are used to operate the brushless motor at the commanded speed. The motor controller also sends feedback signals back up to the main control center.

Due to the high frequency of communication between the motor controller and brushless motor, the two components need to be located close to one another. This is the primary reason for having the motor controller located directly on the SolarBee.

All electronic connections on the SolarBee equipment should only be used for the inputs or outputs that they are labeled and designed for. If any of the leads going into the electronic controller are disconnected, be sure when re-connecting to place them in the proper position.

Wiring - All electric wiring includes corrosion-resistant, industrial cords with molded, weather and watertight connectors. The connectors are indexed to prevent improper wiring. A general electrical schematic can be found in the Maintenance and Field Adjustment section.

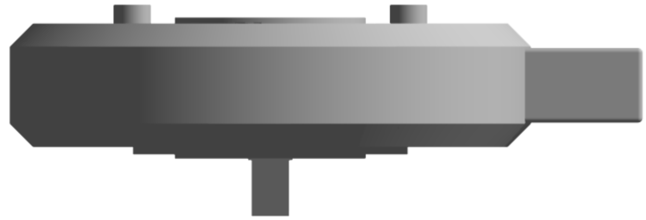
Motor Control Cord



Durable Wiring And Connectors

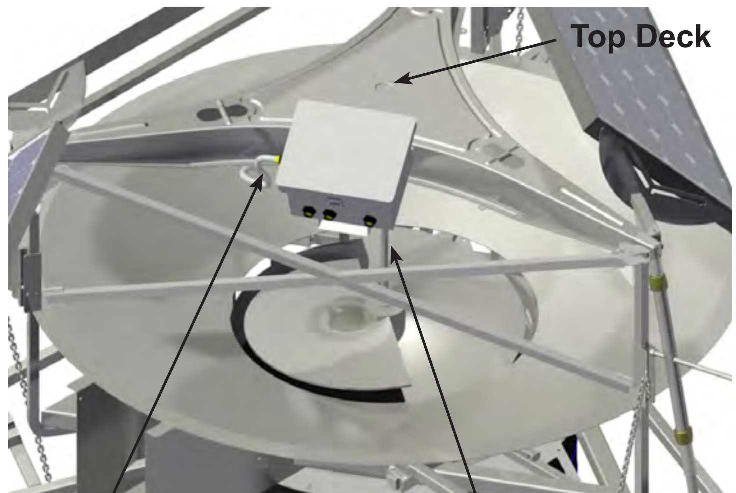
Brushless Motor / Impeller

Brushless Motor - The brushless motor is located directly below the Top Deck. 4 bolts run down through the Top Deck and into the housing of the brushless motor fastening it onto the machine.



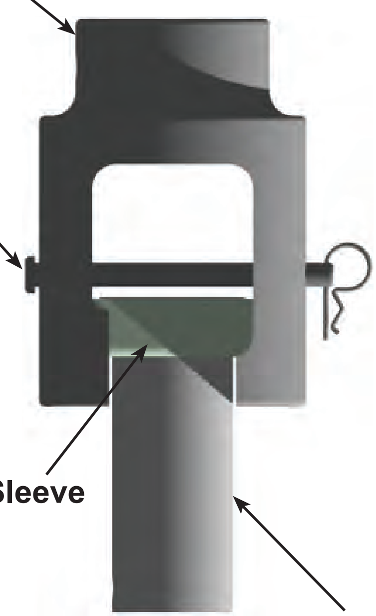
Brushless Motor

CAUTION: THE BRUSHLESS MOTOR WEIGHS APPROXIMATELY 36KG (80 LBS). DO NOT REMOVE WITHOUT DISCUSSING THE PROCEDURES AND EQUIPMENT NECESSARY WITH A SOLARBEE SERVICE TEAM MEMBER.



The brushless motor is built to be very durable. The housing is constructed of casted aluminum. The brushless motor runs very quietly and smoothly. It does not require any maintenance. A drive shaft extends through the bottom center of the housing.

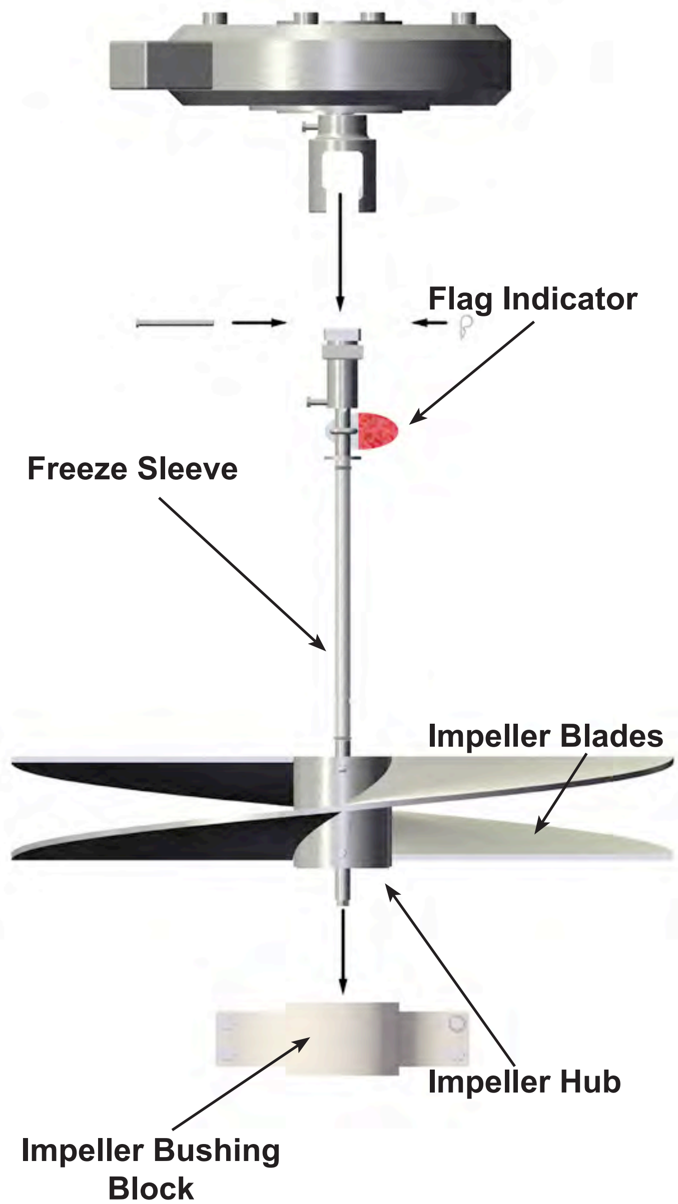
Shaft Coupling - The shaft coupling connects the brushless motor drive shaft to the impeller shaft. The shaft coupling is located directly below the brushless motor and is made up of 3 main components. These components are called the upper coupling, lower coupling, and coupling sleeve. The shaft coupling is designed to allow quick disconnect for removal of the impeller assembly. Disconnecting the impeller shaft from the brushless motor shaft is simply accomplished by pulling out a pin and requires no tools. The upper coupling remains attached to the brushless motor while the lower coupling and coupling sleeve remain on the impeller shaft.



Impeller Assembly - The impeller assembly is made up of the stainless steel impeller shaft, stainless steel flag indicator, freeze sleeve, stainless steel impeller blades, and plastic impeller bushing. The impeller assembly is easily removed by pulling a pin on the shaft coupling.

Turn SolarBee Off Before Performing Maintenance

CAUTION: KEEP BODY APPENDAGES OR LOOSE CLOTHING AWAY FROM THE IMPELLER ASSEMBLY WHILE THE MACHINE IS OPERATING! IF MAINTENANCE IS REQUIRED, BE SURE TO TURN THE SOLARBEE OFF FIRST!



The flag indicator is fixed to the shaft and used as a visual indicator of the impeller shaft's rotational speed.

A food grade oil-filled, Teflon freeze sleeve secured with o-rings surronds the impeller shaft. The freeze sleeve is free to rotate on the shaft. If the water should freeze around the machine, the freeze sleeve will stand still, frozen in by the ice, but inside the plastic sleeve, the impeller shaft will be turning.

The impeller blades are welded to a hub that is fastened to the impeller shaft. The impeller is designed to gently pump water from below and can handle up to 10cm (4-inch) spherical solids.

The impeller bushing is a smooth collar that the impeller shaft tip fits into. The impeller bushing aligns and centers the impeller shaft within the machine.

Distributor Dish / Hose / Intake Plate

The distributor dish, structural members, structural fasteners, and mounting brackets are constructed of stainless steel.

Distributor Dish - Near-laminar flow is achieved by the SolarBee due to its uniquely designed distributor dish. The impeller rotates while sitting within the lower half of the distributor dish. There are also small water passages located below the dish to strengthen the induced flow effect (water movement occuring between the lower water layer entering the machine and the upper water layer leaving the dish).

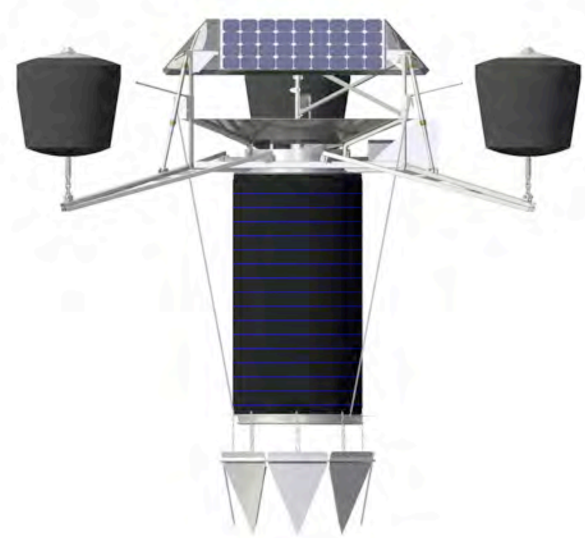
The top lip of the distributor dish is set approximately 5.1cm to 6.4cm (2- inch to 2.5-inch) below the surface of the water to achieve best flow results. The distributor dish depth is set by rotating the turnbuckles located on the float arms.

Hose / Intake Plate - The hose offers flexibility in adjusting the intake level where the machine will draw water from.

The high wave intake plate is designed to draw water horizontally into the hose even when experiencing high wave conditions. The intake plate is split into two parts, and held together by a hinge. The buoyant halves allows the intake to remain horizontal during calm and light wave surface conditions. As the machine rides up a high or violent wave, the force of the escaping water forces the intake halves to open, releasing the water out the bottom of the hose. The intake then closes as the high wave passes to continue horizontal circulation.

Distributor Dish

Hose With High Wave Intake Plate Closed

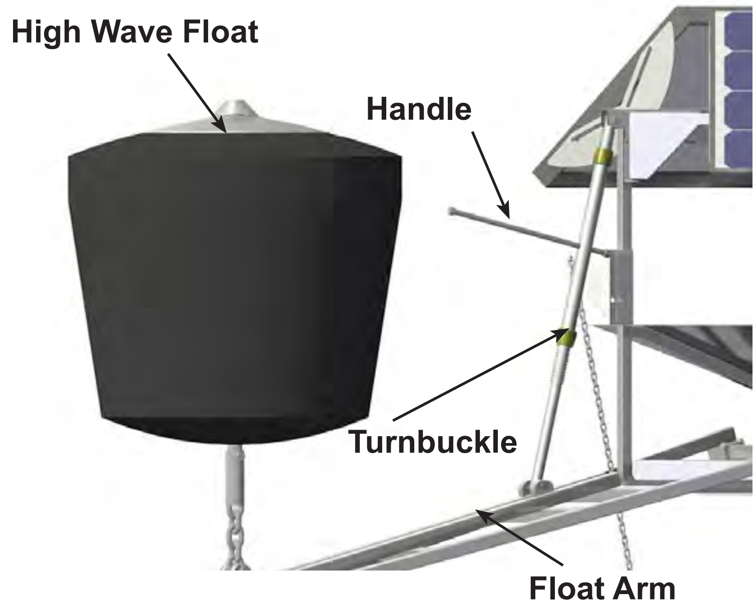


Hose With High Wave Intake Plate Open

Float Arms / Floats

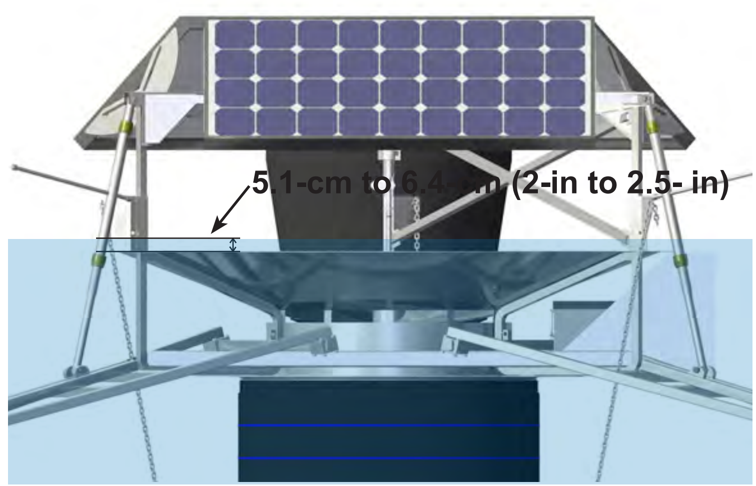
The SolarBee contains 3 float arms and 3 floats. The float arms allow vertical positioning of the machine and the floats provide buoyancy.

Float Arms - The float arms are constructed of stainless steel components. They connect the floats to the central machine structure. Each float arm has a sturdy turnbuckle. The turnbuckles can easily be rotated to adjust the vertical height of the distributor dish. Lengthening the turnbuckle (rotatating clockwise) will raise the lip of the distributor dish, whereas shortening the turnbuckle (rotating counter-clockwise) will cause the lip of the distributor dish to lower.



The turnbuckle and float arm structure components are constructed with robust stainless steel materials allowing the SolarBee to operate in severe environments without being damaged. The turnbuckle is self locking. Simply rotate the handle to expand or collapse the turnbuckle for dish depth adjustment.

It is important to check the distributor dish depth routinely. The SolarBee naturally drops into the water over time due to biomass buildup and trapped air escaping from the hose. If the distributor dish lip is too high, the water flowing off the lip may become turbulent and the flow rate of the machine may reduce.

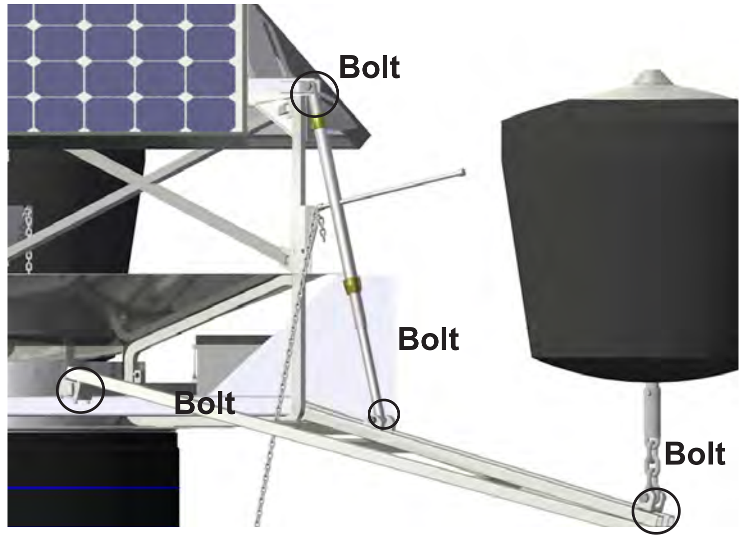


Distance Between Distributor Dish And Water Level

If the distributor dish lip is too low, the water coming off the lip will flow just beneath the surface of the pond and the surface will not be renewed.

Each float arm is connected to the central machine structure with 3 bolts. Each float is connected to the float arm by 1 bolt. The turnbuckle can be removed from the float arm by removing the lower turnbuckle bolt, but should only be done when the unit is resting on the shore.

If re-attaching the turnbuckle to the float arm, be sure that each threaded end of the turnbuckle together are screwed all the way in or all the way out before re-attaching. If threaded ends are not equally expanded or collapsed before fixing the ends, the turnbuckle will have limited adjustment.



Float Arm Connection Points

Floats - The SolarBee has 3 floats, made from high density Polyethylene. The floats are filled with a Polystyrene closed-cell foam for long term buoyancy. The floats have a uniquely designed shape to:

- Minimize the interference with the water flow on the surface coming off the distributor dish.
- Have a low profile above the water for minimizing wind resistance and offering less exposure to vandalism.
- Avoid being crushed by ice pressure.
- Provide extra buoyancy when needed without going much deeper into the water.
- Have independent freedom to move by having a central pivot point on the bottom side of the float.
- Move freely allowing waves to apply forces to the float which does not transfer to other machine components.

CAUTION: DO NOT REMOVE ANY FLOAT ARM OR TURNBUCKLE PINS OR BOLTS WHILE THE SOLARBEE IS FLOATING IN THE WATER! THE SOLARBEE MUST BE RESTING ON THE GROUND OR SAFELY SUPPORTED TO RELIEVE THE FORCES ON THE FLOAT ARM AND TURNBUCKLE STRUCTURES PRIOR TO DISASSEMBLY! FAILURE TO FOLLOW THIS WARNING COULD LEAD TO SINKING THE SOLARBEE, OR CAUSE SERIOUS INJURY!

Float

Anchoring / Mooring Block System

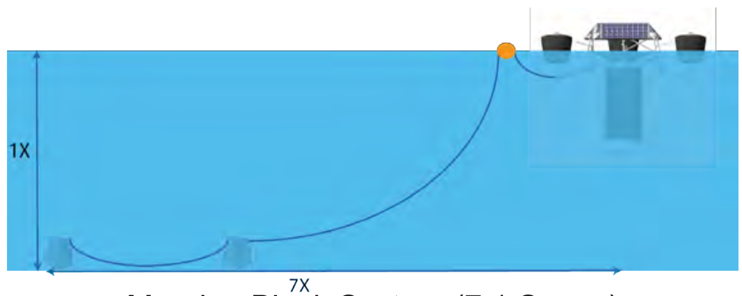
The mooring block system consists of two mooring blocks made of high density Polyethylene with smooth, rounded bottoms. The smooth bottoms prevent any damage being done to a pond liner or reservoir bottom. The mooring blocks are concrete filled and weigh approximately 31.75 kg (70-lbs).

Stainless steel anchor chain is used to connect the mooring blocks to the SolarBee at the float plate on one of the floats. The anchor chain contains swivels approximately every 4.5m (15-ft) to prevent the chain from twisting and tangling.

A 7:1 scope is generally preferred for the length of anchor chain. For example, if the pond is approximatley 3m (10-ft) deep, the anchor chain will go from the first mooring block out 21m (70-ft) to the machine. The 7:1 scope prevents the machine from moving during high wind and wave conditions. The two mooring blocks are generally spaced apart along the anchor chain by a slightly greater than the maximum water depth. From time to time, as determined by specific circumstances, the scope can be reduced to 5:1.

Following severe weather conditions (greater than 129 km/hr (80-mph) wind, higher than 1.2m (4-ft) waves, or ice thaw), it is possible for the SolarBee to drag the anchors and move out of position. If this should happen, the pond or reservoir operator will need to re-locate the machine to its original position.

Movement of machine - For a SolarBee anchored by a mooring block system, the machine may rotate 360 degrees around the mooring blocks on a radius of approximately 5X to 7X the water depth. For example, a machine that is in 10 ft (3m) of water may travel on a 70 ft (21 m) radius from the location of the mooring blocks



Mooring Block System (7:1 Scope)

WARNING: IF MOVING OR DEPLOYING MOORING BLOCKS CONNECTED TO THE ANCHOR CHAIN, BE SURE THAT YOU AND OTHERS ARE CLEAR OF THE ANCHOR CHAIN BEFORE SINKING THE MOORING BLOCKS! LOWER THE MOORING BLOCKS INTO THE WATER SLOWLY. FAILURE TO DO SO COULD CAUSE SERIOUS INJURY OR DEATH BY DROWNING!

Maintenance and Field Adjustment

The performance of the SolarBee has proven to increase tremendously when its operator understands the operation of the machine and knows how to carry out field adjustment procedures. During installation, an experienced SolarBee field team thoroughly trains the operator on how to keep the SolarBee performing at its best.

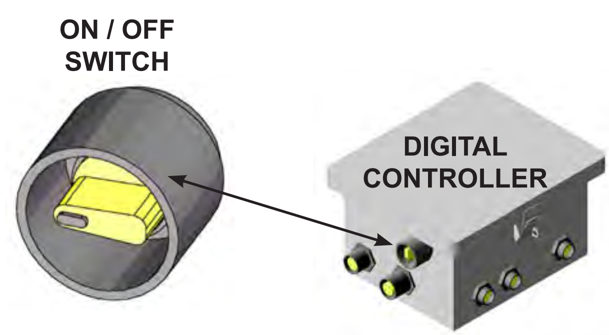
SolarBee Orientation During Install

In most applications, it is strongly encouraged that the operator have a boat to perform routine checkups and field adjustment procedures on the SolarBee. A large, expensive boat isn't necessary. Our SolarBee field teams use 12 ft (3.65m) Jon boats that work fine for almost all applications.

It is extremely important that safety comes first every time the SolarBee is inspected or having maintenance procedures performed. It is strongly encouraged that anyone working on or near the machine follow these rules:

- Wear a personal floatation device
- Stay focused and alert
- Turn the SolarBee off before working on it
- Stay clear of parts while they are moving

To turn the SolarBee motor off, turn the On / Off switch to the off position. To completely power down the digital controller, remove all power sources in the proper sequence.



PV Module Cleaning

The solar panels are the SolarBee's primary source of energy, so it is important that they be kept clean. Over time, dust collects on the PV modules or birds are not kept completely off by the bird deterrent resulting in the panel's effective surface area decreasing.

PV Module Cleaning

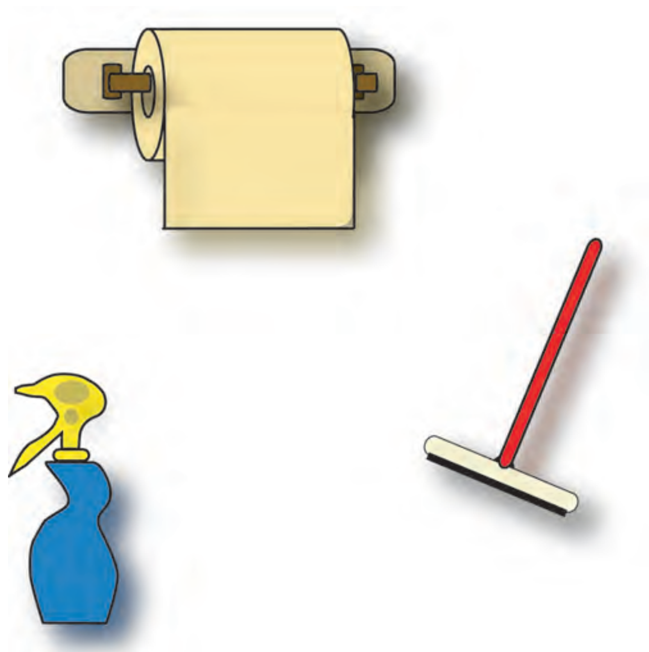
TOOLS RECOMMENDED:
Squeegee
Glass Cleaner
Paper Towel or Wash Cloth

STEP 1: Rinse panel face off with water.

STEP 2: Use squeegee, towel, or wash cloth to clean surface of panel.

STEP 3: Remove any streaks or films using glass cleaner and paper towel/wash cloth.

STEP 4: Repeat Steps 1 through 3 for each solar panel.



Solar Panel Angle Adjustment

The SolarBee technology includes tilting PV modules to allow for optimal solar collection for different geographical regions and changing sun position during the seasons.

Use 35 Degree (Flattest Position):
Where - Locations less than 40 degree latitude.
When - During fall, summer, and spring or year round if no adjustment is preferred.

OR

Where - Locations greater than 40 degree latitude.
When - During summer only.

Use 45 Degree (Middle Position):
Where - Locations greater than 40 degree latitude.
When - During spring and fall or year round if no adjustment is preferred.

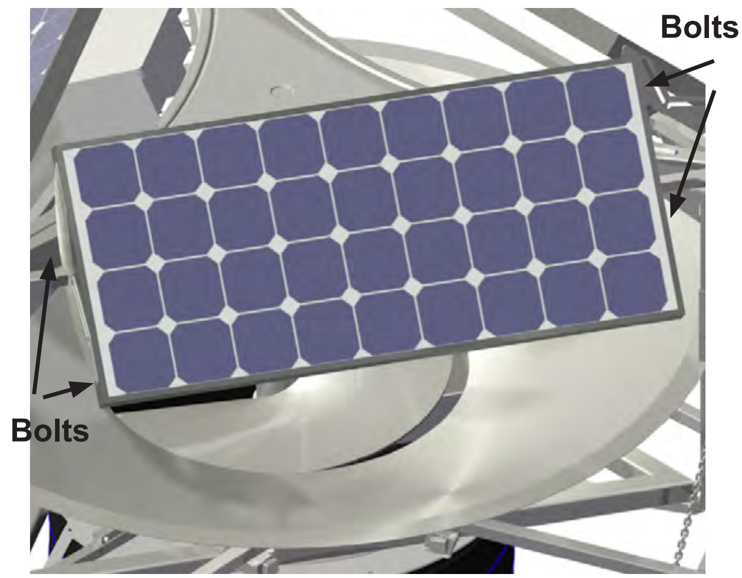
OR

Where - Locations less than 40 degree latitude.
When - During winter

Use 55 Degree (Steepest Position):
Where - Locations greater than 40 degree latitude.
When - During winter season or periods of abundant snow (The steep angle will help prevent snow from building up on the panels).

TOOLS RECOMMENDED:
Two 13mm wrenches

STEP 1: Loosen 2 bolts on each end of the PV module using 13mm wrenches as shown in the figure below.



STEP 2: Firmly grip the PV module and slide it up or down the tracks until it is in the desired position. For each of the three recommended angle settings listed, there is a slot in the top tracks at both ends that the top bolt will drop into.

STEP 3: Once the PV module is in the desired position, tighten all four bolts.

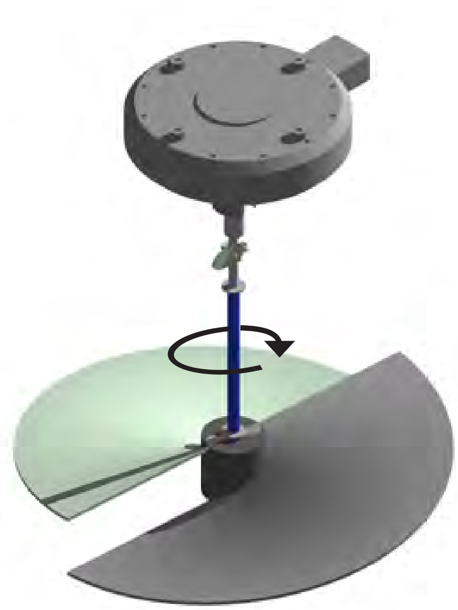
STEP 4: Repeat steps 1 through 3 for other two solar panels

Impeller Rotational Speed Check

During clear skies and good sunlight weather conditions, the drive system of the SolarBee unit should operate:

1) At a rotational speed between 55 and 85 revolutions per minute (rpm).

2) In a clockwise direction when looking down at the impeller.

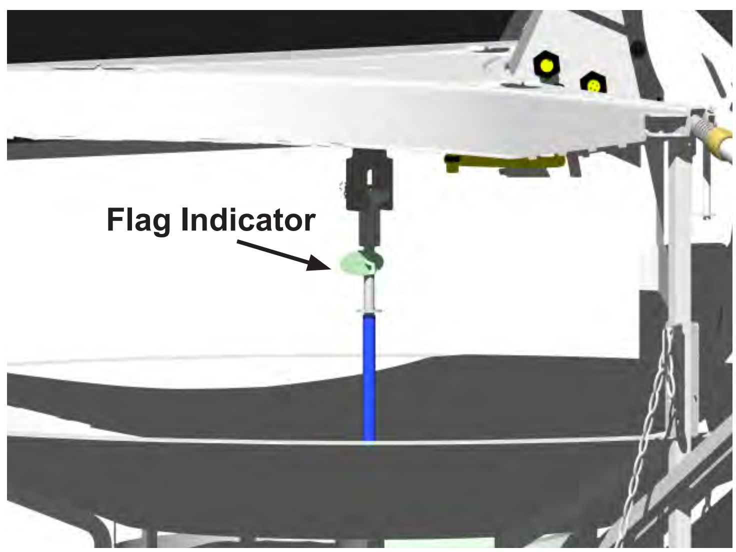


Clockwise Rotation When Looking Down

Checking Rotational Speed

TOOLS RECOMMENDED:
Watch or Stopwatch

STEP 1: Locate the flag indicator on the impeller shaft.



Flag Indicator Section of Impeller Shaft

STEP 2: Start the stopwatch or mark a starting point on the watch. Immediately begin counting each full revolution of the flag indicator (starting with "ZERO", "ONE", "TWO", etc) for a time of less than or equal to 1 minute and at least 20 seconds. This step is easier with two people, one counting revolutions and the other keeping track of the time expired.

STEP 3: Quit counting revolutions and immediately observe how much time has expired in seconds.

STEP 4: Use the following equation to calculate rotational speed in rpms:

$$\text{Revolutions Per Minute (RPM)} = \frac{(\text{\# Revolutions Counted X 60})}{\text{\# Seconds Expired}}$$

(DIVIDED BY)

Example: 30 Revolutions were counted in a time period of 30 seconds.

RPM = (30 revolutions X 60) / (30 seconds) = 60

Impeller Rotational Speed = 60 RPMs

Impeller Cleaning

In some applications, the autoreverse function will not completely eliminate floating debris or aquatic weeds from catching on the impeller blades and shaft. In these applications, impeller cleaning and impeller removal may be necessary.

SolarBee With Buildup On Impeller

CAUTION: TURN SOLARBEE OFF BEFORE WORKING NEAR IMPELLER! WEAR PROTECTIVE GLOVES AND BE CAUTIOUS OF SHARP LEADING EDGES ON IMPELLER BLADES WHILE CLEANING! FAILURE TO FOLLOW THESE WARNINGS COULD LEAD TO INJURY!

Impeller Cleaning

TOOLS RECOMMENDED:
Elbow High Rubber Gloves
Squeegee
Garbage Bag

STEP 1: Turn SolarBee off by placing the On/Off switch into the OFF position.

STEP 2: Open PV module gate for easy access to the impeller. If necessary for better access, use the three turnbuckles to raise machine level.

STEP 3: Using gloves and squeegee, clean off debris or aquatic weeds that are wrapped around impeller blades and shaft. Place the debris into a garbage bag and remove from pond to prevent it from going through SolarBee again. **Follow all local laws and regulations when disposing of any materials collected.**

STEP 4: Observe if there is buildup below the impeller blades.

If below the impeller is clean, then close the PV module gate, lower dish into the water at proper setting using the turnbuckles, and screw in fuse switch to turn SolarBee back on.

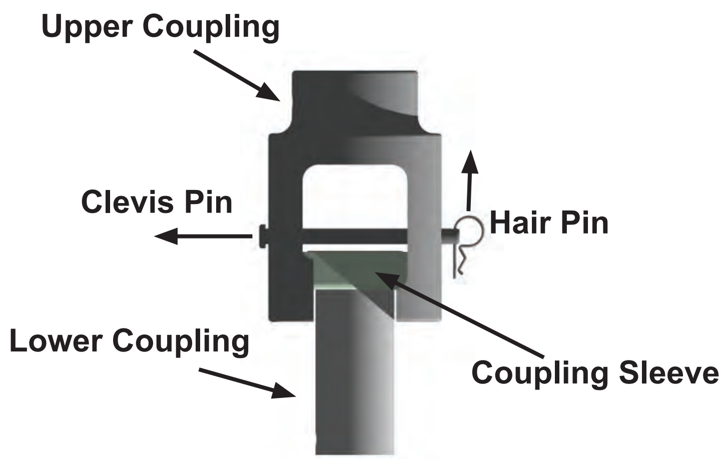
If there is buildup below the impeller, then see directions for impeller removal on the next page.

Impeller Removal For Buildup Below Impeller

Impeller Removal

In the case that there is buildup below the impeller that cannot be reached, the impeller assembly can easily be removed.

Impeller Removal
TOOLS RECOMMENDED:
Elbow High Rubber Gloves
Garbage Bag

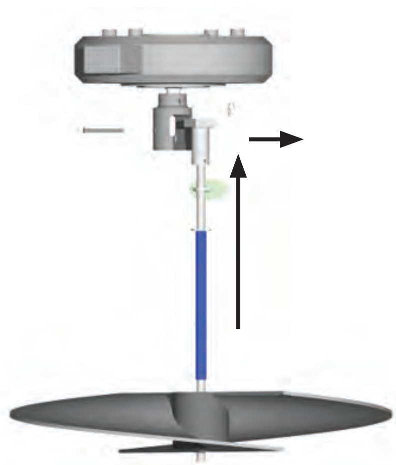


STEP 1: With SolarBee machine off and PV module gate open, locate the clevis pin going through the upper shaft coupling. Remove the hair pin and pull clevis pin out.

STEP 2: Grab the impeller shaft below the flag indicator, lift up and then outward until lower coupling and shaft are disconnected from upper coupling and brushless motor.

STEP 3: Observe and clean any debris located on the bottom of the impeller.

STEP 4: Observe and clean any debris located down in the dish where the impeller rests. Place the debris into a garbage bag and remove from pond to prevent it from going through SolarBee again. **Follow all local laws and regulations when disposing of any materials collected.**

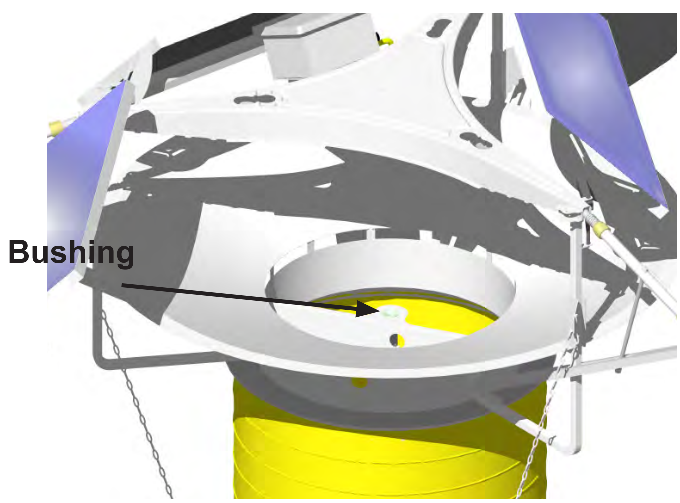


Impeller Assembly Removal Motion

STEP 5: Once clean, place impeller assembly back in place (Slide lower coupling into upper coupling and allow to drop down into place). Be sure bottom of impeller shaft fits into the bushing in the dish and that the coupling sleeve is in place inside the shaft coupling assembly.

STEP 6: Place clevis pin back through upper shaft coupling and secure with hair pin.

STEP 7: Close PV module gate and turn SolarBee machine back on.



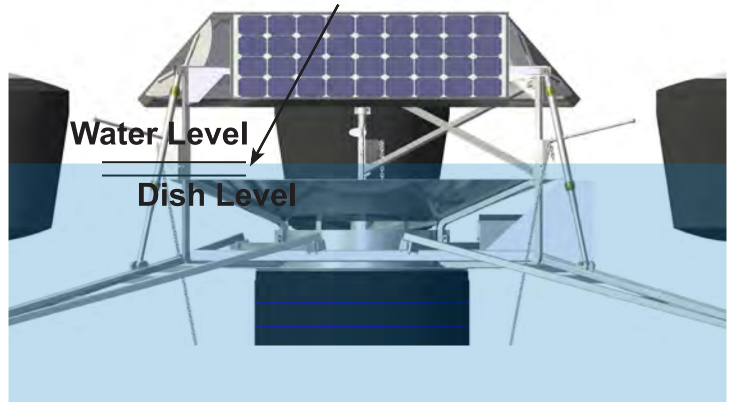
Impeller Assembly Removed

Distribution Dish Level Setting

The SolarBee distributor dish depth in the water is a key factor in maintaining the near-laminar flow of water coming off the machine.

The distribution dish level setting is measured from the top lip of the dish up to the water surface. For this SB10000HW , the depth level should fall on or between this range:

5.1cm to 6.4cm (2.0 inches to 2.5 inches)



Distance Between Distribution Dish And Water Level

Distribution Dish Level Adjustment

TOOLS RECOMMENDED:

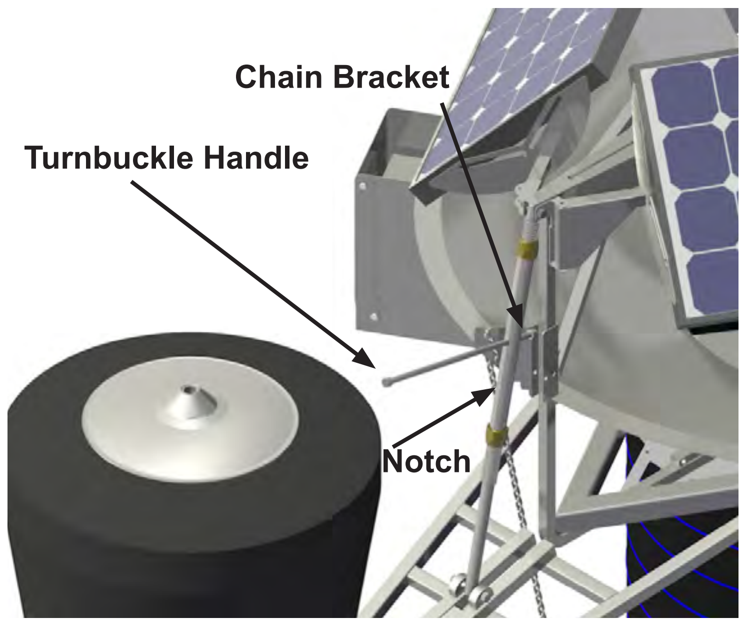
Tape Measure or Ruler

STEP 1: If SolarBee is not on, turn the On/Off switch to the On position.

STEP 2: Observe if the dish level is too deep or not deep enough at the three locations where each float arm extends out from the machine. This can be done using a tape measure or locating the notch on each chain bracket for machines having a hose. If using the notch on each chain bracket, the water level should be even with the appropriate notch (see picture).

STEP 3: Set the dish to the correct level in each of the three locations. To raise the dish level, rotate the turnbuckle around (clockwise) so that it is expanding. To lower the dish level, rotate the turnbuckle around (counter-clockwise) so that it is compressing.

STEP 4: Double check dish level at all three locations and fine tune as necessary.



Water Level Even With Notch On Chain Bracket

Dish Depths For Different Models of SolarBees

Hose Intake Setting

The hose intake depth is a critical factor that determines what effects the SolarBee will have in your application. In some cases, the hose intake depth will need to be field adjusted to fine tune the SolarBee following installation.

SolarBee With Depth Indicator Chain Down To Intake

Hose Intake Adjustment

TOOLS RECOMMENDED:

No tools are necessary

STEP 1: Determine the new hose intake setting after consulting with a SolarBee service team member.

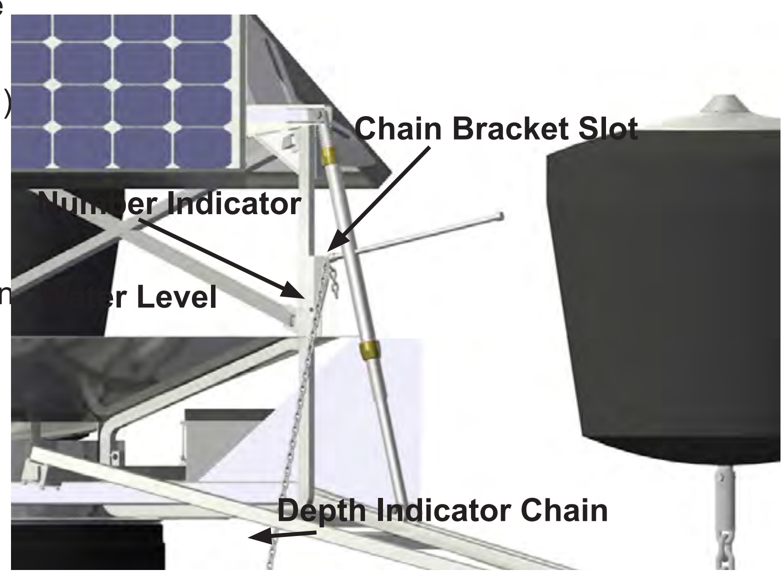
Hooking Depth Indicator Chain Into Slot

STEP 2: Locate one of the three chain brackets. Observe which number on the depth indicator chain is nearest to the water surface. That number is the current depth in feet of the hose intake.

STEP 3: Lift the depth indicator chain out of the chain bracket slot. Raise or lower the chain no more than a 0.5m (2 ft) increment and slide back into chain bracket slot. In some applications having longer hoses, each chain may need to be raised using only 15cm (6 inch) increments.

STEP 4: Repeat Step 3 for the other two chain brackets. Again, do not raise or lower the chain more than 0.5m (2 ft) increments at a time.

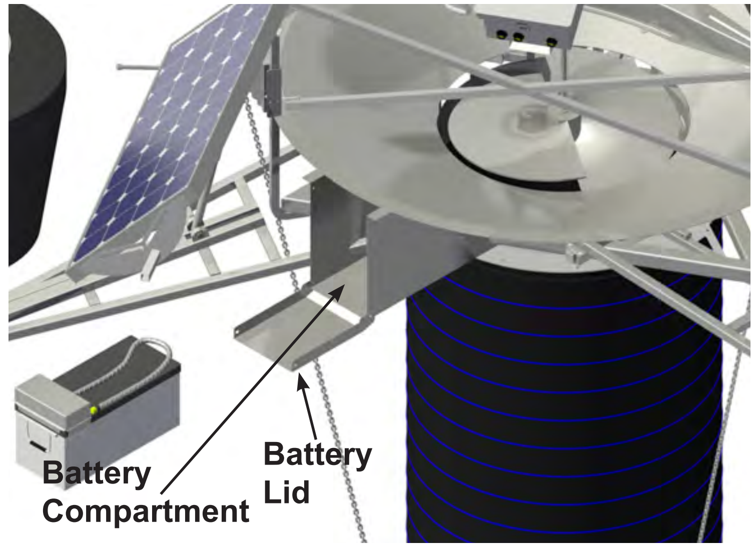
STEP 5: Repeat Steps 3 and 4 unitil the number closest to the water surface on each depth indicator chain represents in feet, the new desired depth setting of the hose intake.



Close Up View Chain Brakcet And Depth Indication

Battery Replacement

The SolarBee contains an onboard battery just below the dish that will require infrequent replacement. Between 2 and 3 replacments are expected over the course of the machine life.

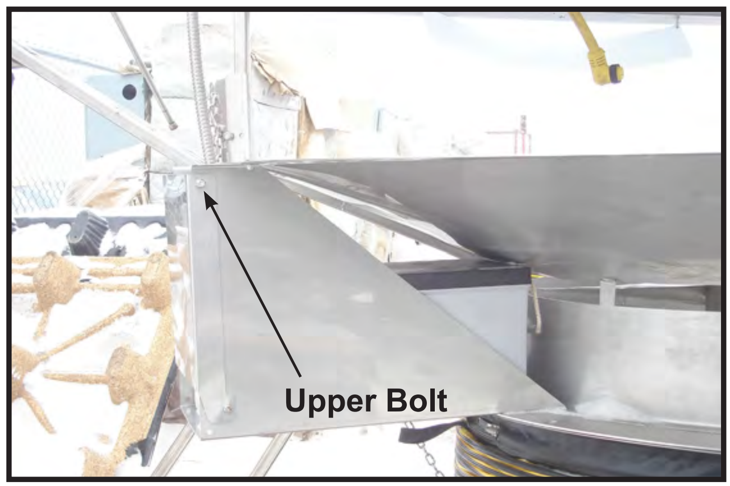


Battery Replacement

TOOLS RECOMMENDED:
13 mm wrench
13 mm socket wrench

STEP 1: Extend all 3 turnbuckles out all the way to raise the machine out of the water enough to expose the entire battery compartment.

STEP 2: Open the PV gate over the controller and perform a complete power down procedure on the SolarBee (be sure battery lead is disconnected from controller).



STEP 3: With the SolarBee off, locate the battery compartment below the SolarBee distribution dish.

STEP 4: Using the 13mm wrenches, loosen and remove the upper bolt and locking nut. This will allow the battery lid to be opened up. (If possible, allow the battery lid to lay down on a stable part of the boat)

STEP 5: First fish through the battery lead from the back of the battery compartment, then pull the battery out into boat.

STEP 6: Install new battery into position and fish battery lead through the back of the battery comparment.

STEP 7: Close the battery lid and tighten bolt and nut to secure in place.

STEP 8: Completely power up SolarBee, close panel gate, and reset dish depth.

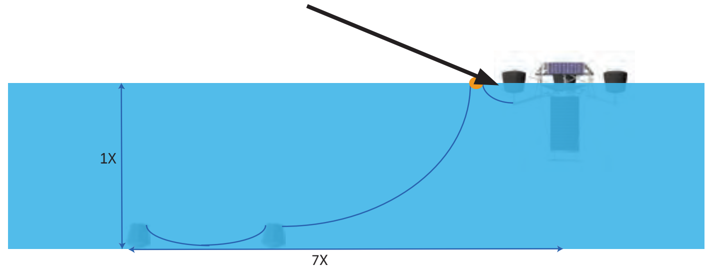
Battery Disposal: Be sure to follow local law and regulations when disposing of the used up battery!

Battery Lid Down, Battery Lead Out

Repositioning The SolarBee

Under some circumstances, the SolarBee unit may need to be moved or placed back into its original location if severe weather hits.

Anchor Chain Connection



SolarBee Anchored With Mooring Block System

Repositioning Mooring Block Systems

TOOLS RECOMMENDED:
Motor Powered Boat

STEP 1: Locate the anchor chain connection point to the SolarBee.

STEP 2: Begin pulling the anchor chain slack until your boat is directly above the first mooring block. Pull up on the anchor chain and pop the first mooring block loose. Once the first mooring block is popped free, pull up more anchor chain and pop the second mooring block.

STEP 3: Once both mooring blocks are loose from the bottom, pull them up so they are off the bottom and tie them off the boat. The mooring blocks don't need to be pulled completely out of the water, just high enough so they won't hit the bottom when you are moving.

STEP 4: Pull the SolarBee with the suspended mooring blocks to the desired location using the boat.

STEP 5: Untie the anchor chain from the boat letting the mooring blocks fall to the bottom. Stay clear of sinking anchor chain!

WARNING: WHEN SINKING THE MOORING BLOCKS, BE SURE TO STAY CLEAR OF THE SINKING ANCHOR CHAIN! LOWER THE MOORING BLOCKS INTO THE WATER SLOWLY. FAILURE TO DO SO COULD RESULT IN SERIOUS INJURY OR DEATH BY DROWNING!

Winter Conditions

In some locations, heavy snowfall and frigid temperatures may be present during the winter season. During these conditions, it is possible that the SolarBee becomes frozen in by ice and snow causing it to stop turning.

The SolarBee is designed to avoid being damaged when it is stalled and as the ice starts to melt it will start back up again.

When the SolarBee is beginning to freeze in or starting to thaw out, the ice around the machine is not stable enough to support weight. Also, in many cases, one cannot recognize that the ice is thin around the machine. For this reason, it is highly recommended that the SolarBee should NOT be approached during the period of time it is frozen in.

In some locations there may be public access or recreation such as ice fishing, snowmobile traffic, or other activities on the water body during winter. For these locations, ***SolarBee strongly recommends turning the machine off*** by late fall (Nov 15th in U.S.) before freeze up. The area around the SolarBee would then freeze in solid as the rest of the lake does, decreasing the chance of a serious accident near the machine. ***If these recommendations are not followed, the SolarBee will cause thin ice several meters around the vacinity of the SolarBee creating a very large hazardous area.***

When it is desired for the SolarBee to freeze in and the location requires the SolarBee to be turned off in late fall, it is important to verify that the machine is not operating prior to ice formation. Once winter passes and the ice melts away, the machine should be turned back on to get an early spring start.

SolarBee In A Lake That Is Partially Frozen

WARNING: DURING WINTER CONDITIONS WHEN THE SOLARBEE IS FROZEN IN OR PARTIALLY FROZEN IN, THE MACHINE SHOULD NOT BE APPROACHED. THE ICE AND SNOW AROUND THE SOLARBEE SHOULD NOT BE ASSUMED TO SUPPORT WEIGHT. FAILURE TO DO SO CAN RESULT IN SERIOUS INJURY OR DEATH BY DROWNING OR HYPOTHERMIA!

SolarBee Completely Frozen In

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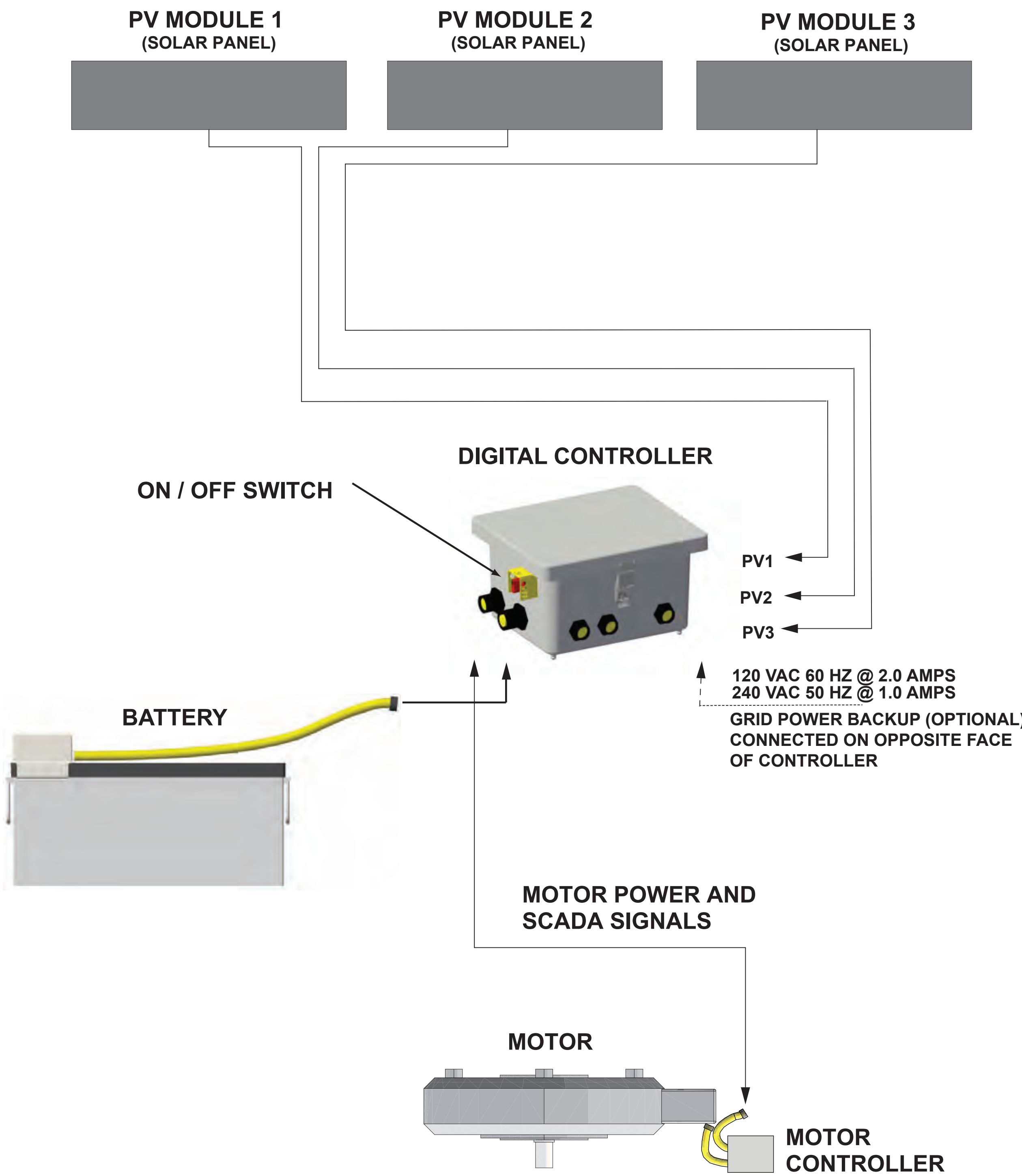
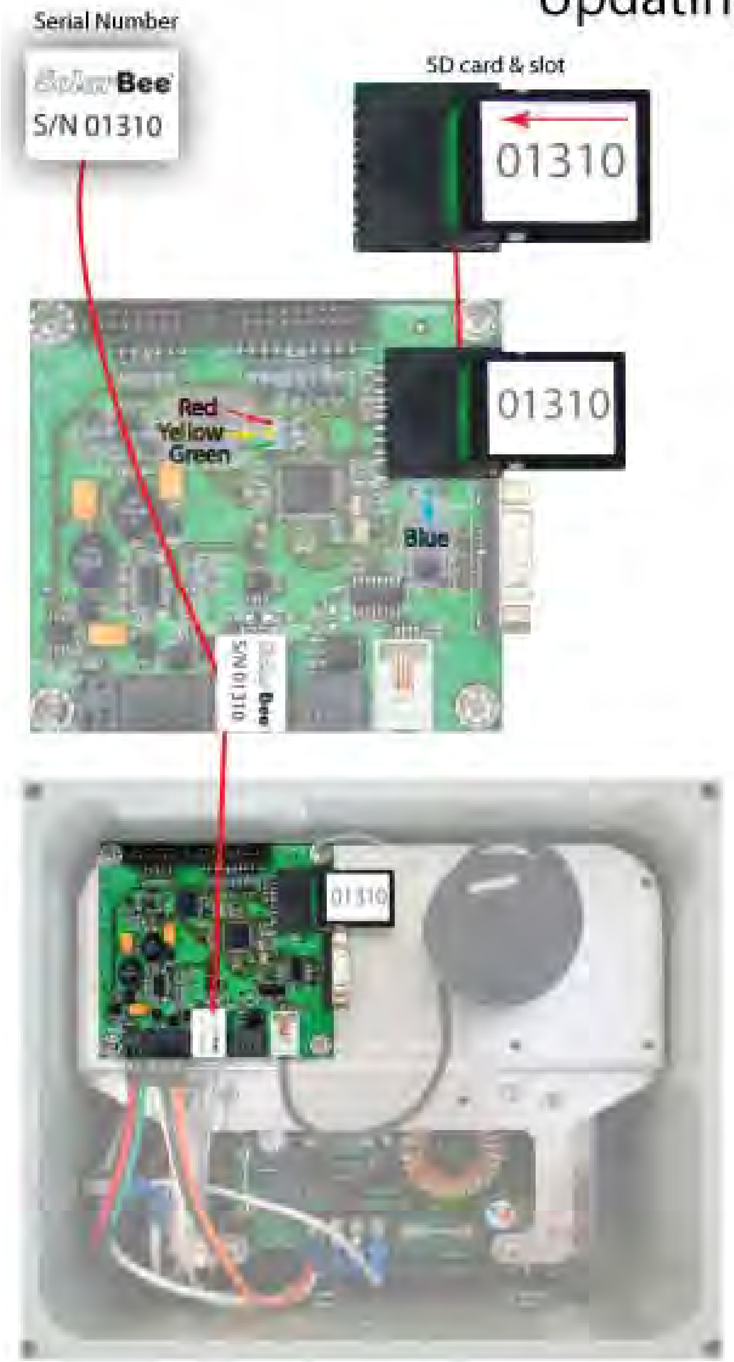
GENERAL ELECTRICAL SCHEMATIC FOR SOLARBEE



Updating the SolarBee via the SD card



1. Match the number on the SD card to the serial number. If your card does not have a number, skip this step.	
2. Insert the SD card into the slot. Push the card in all the way. The blue light beside the slot will come on.	
3. Once the correct files have been found, the green light will begin to flash rapidly. Leave the card inserted.	
4. When it is time to remove the card, the green and yellow lights will flash rapidly and be alternating. Remove the SD card from the slot.	
5. When the card is removed, the red light will flash rapidly. This is the beginning of the self programming with instructions received from the SD card. After the red light is finished, the yellow light will flash rapidly, followed by the green light.	
6. Upon completion the brainboard will restart and perform a check. A successful update will display the red light blinking once followed by one yellow blink and one green. If you miss this or are unsure, you can insert the SD card and perform the update again.	
7. The steady blinking green light should return indicating a healthy machine. If you get two yellow blinks followed by a pause, your SolarBee needs charging but the update is successful.	
8. If the update was not successful, the red, yellow, and green lights will blink together 10 times. The machine will revert to the default parameters. Insert the card to attempt the update again. If it still fails, contact SolarBee Customer Service.	

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Complete Power Down Procedure

NO TOOLS REQUIRED:

STEP 1: Turn the On/Off switch to Off position.

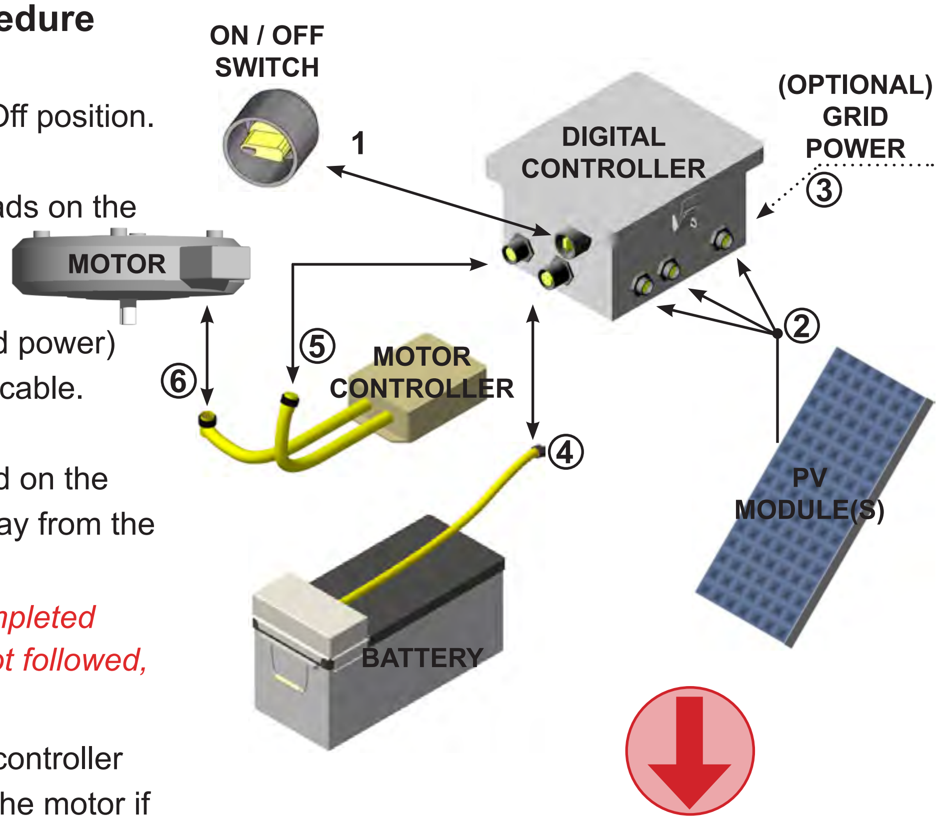
STEP 2: Unscrew all PV module leads on the front side of the digital controller.

STEP 3: Unscrew the on-shore (grid power) connection on the right face, if applicable.

STEP 4: Disconnect the battery lead on the left face. Now all power is taken away from the electrical system.

Be certain steps 1-4 have been completed before continuing. If this order is not followed, component damage may occur.

STEP 5 & 6: Disconnect the motor controller from the digital controller and from the motor if needed.



Complete Power Up Procedure

NO TOOLS REQUIRED:

STEP 1 & 2: Connect the motor controller to the motor and to the digital controller.

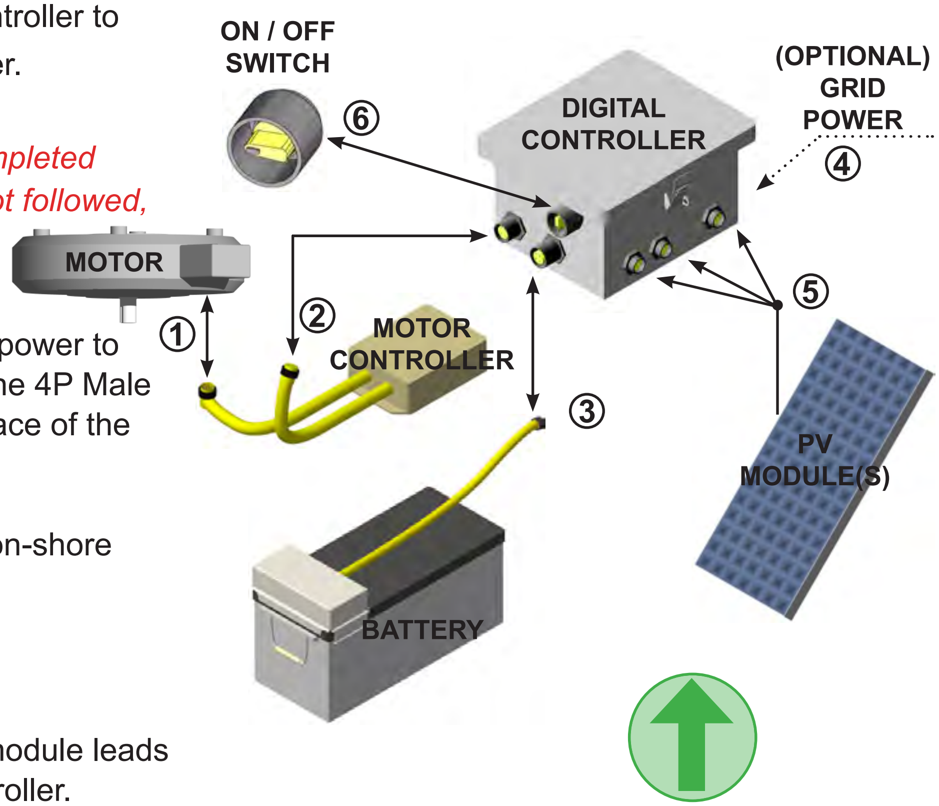
Be certain steps 1-2 have been completed before continuing. If this order is not followed, component damage may occur.

STEP 3: Now you are able to bring power to boot up the system by plugging in the 4P Male connector of the battery to the left face of the digital controller.

STEP 4: If applicable, connect the on-shore (grid power) 2P male connection to the right side of the digital controller.

STEP 5: Connect all available PV module leads into the front face of the digital controller.

STEP 6: Turn the On/Off switch to On position.



SolarBee Troubleshooting

If you find that the SolarBee has quit operating, the following checks can be performed:

Connection Check -
1) Locate the digital controller and be sure that each PV module cord is properly connected.
2) Check that the battery is properly connected.
3) Follow each cord from the electronic controller to its originating component and be sure it is not damaged.

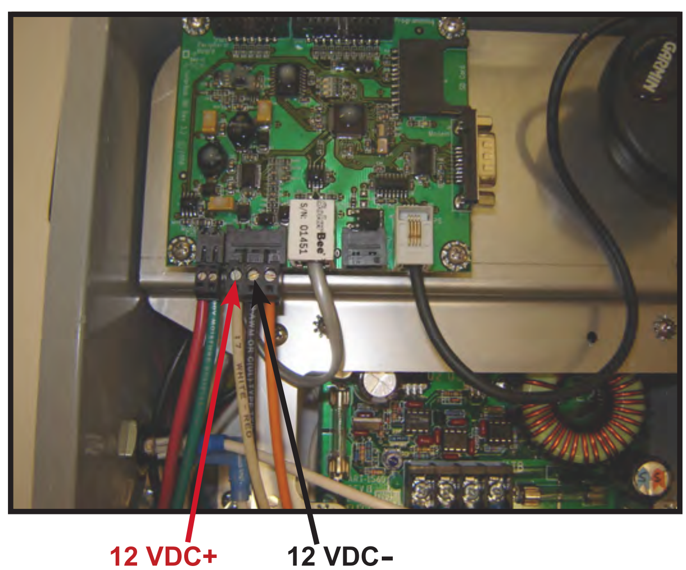
Visual Digital Controller Check - The SolarBee contains an LED (Light Emitting Diode) blink sequence that indicates the machine operation status. The blinking LEDs are found on the Brain-board located inside the digital controller. A solid green LED is also located on the Zahn board. To observe the LEDs,
1) Open the door of the digital controller and locate the laminated LED label on the inside of the door.
2) Using the LED label, locate the Brain-board and the Zahn board. Observe and record the blinking LEDs (color and # of blinks in succession) and solid green LED (off or on).
3) Using the LED label, match your blink observations to the corresponding indication. Use the information on the next two pages to proceed.

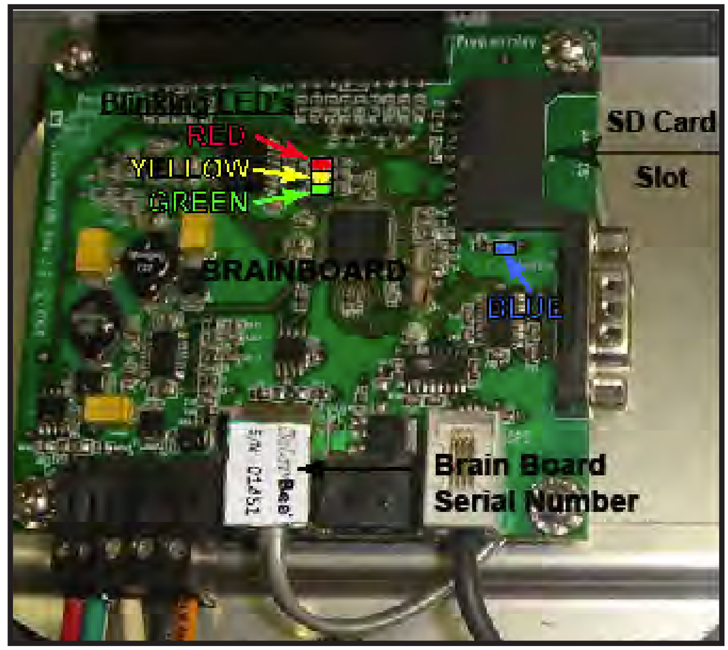
DC Voltage Check -
If a DC voltmeter is available, the battery voltage can be measured off of the brainboard at the 3-pin connection (white, black, and orange leads). 1) Using the voltmeter positive lead on the white screw terminal and voltmeter negative lead on the black screw terminal, the voltage can be measured. 2) Record the measurement.

SCADA Information - SolarBee operation status information can be transmitted from the machine to a nearby monitoring station by using one of SolarBee's various SCADA kits. Contact SolarBee Customer Service for more information.

SolarBee is committed to serving our customers. Feel free to contact a SolarBee Customer Service Representative if you experience any problems with your SolarBee. At SolarBee, we will get you technical support, parts, or a service visit to make sure that your SolarBee is back online in short time. (866) 437-8076 or customerservice@solarbee.com

SolarBee Installation / Service Crew





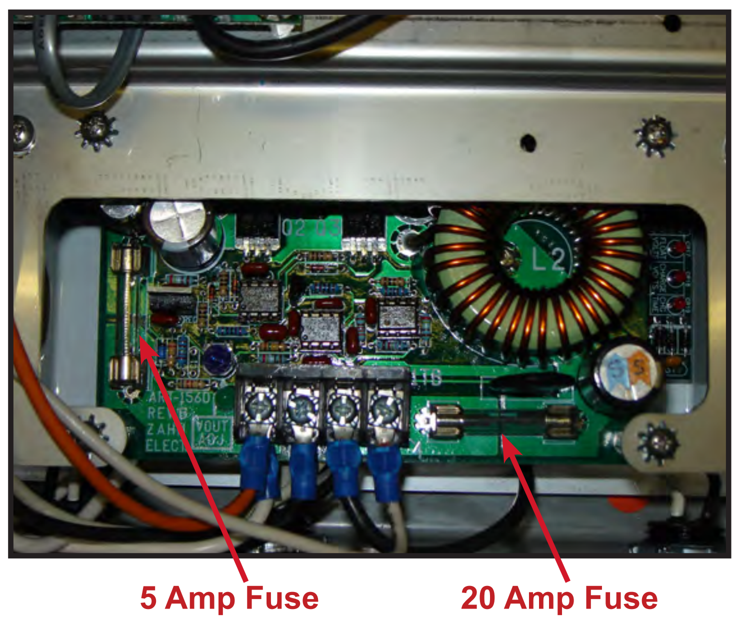
Blink Indication Follow-up Procedures

Blinking Green - System healthy, machine should be operating on programmed run schedule. If not operating on programmed run schedule, contact SolarBee Customer Service.

1X Blinking Yellow - High motor current, check the machine for plugging at impeller and/or strainer-intake.

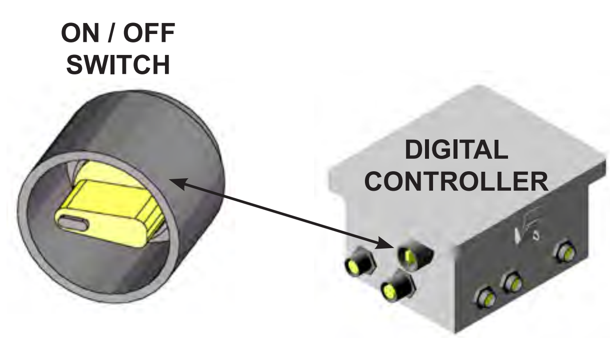
2X Blinking Yellow - Low battery voltage, machine may be operating at reduced speed or temporarily shut down due to cloudy weather period. Re-check machine after sunlight conditions improve.

5X Blinking Yellow - Check GPS connection at Brain-Board (lower right corner). If properly connected and blink code persists, contact SolarBee Customer Service.



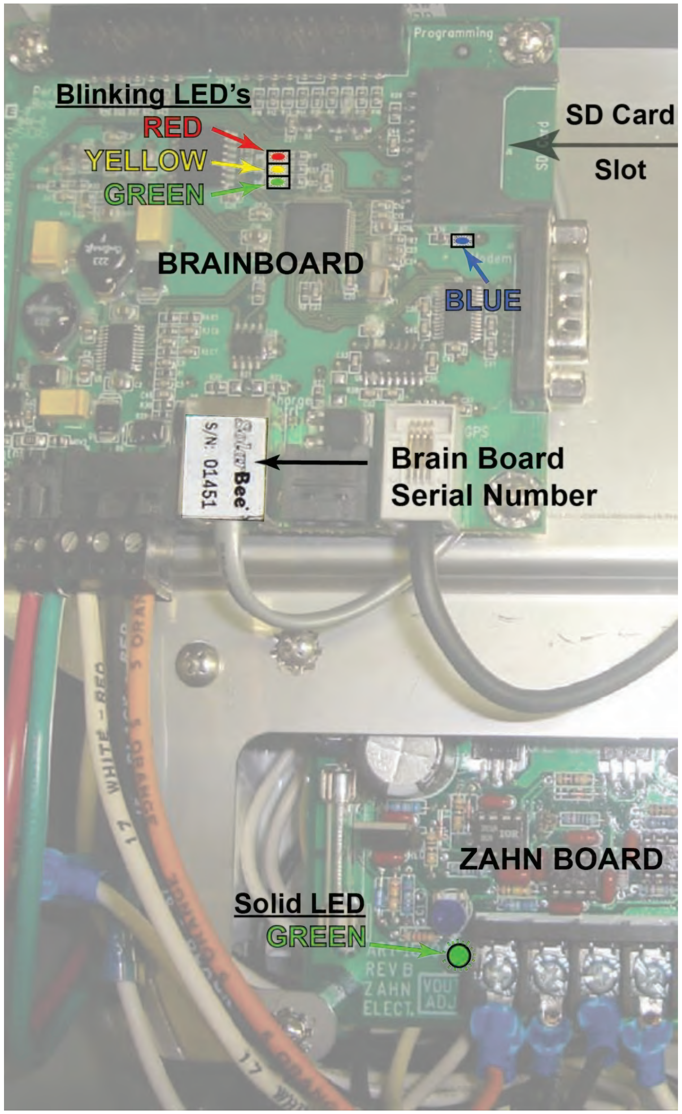
1X Blinking Red - Anti-Jam Routine, machine is operating on a jam removal sequence triggered by high current. Check for plugging only after disconnecting power. If power is not removed first, machine may begin to operate

2X Blinking Red - 36 VDC out of range, machine may be shut down due to blown fuse (glass cylindrical) on the Zahn Board. Left side of Zahn board takes a 5 Amp Fuse, Right side of Zahn board takes a 20 Amp Fuse. Disconnect power before changing fuses. Blown fuses may be difficult to observe, so a continuity tester or new fuse should be used to confirm that the problem is not a blown fuse. If your SolarBee has a fuse switch (20 Amp), check that fuse also.



5X Blinking Red - Battery out of range, machine battery is too low. Check and record battery voltage if possible, then contact SolarBee Customer Service.

For all other blink codes, please contact SolarBee Customer Service.



BEHAVIOR	VISUAL	INDICATION
BLINKING GREEN		HEALTHY SYSTEM
SOLID GREEN, YELLOW, &/OR RED		HARDWARE ERROR
GREEN, YELLOW, & RED OFF		HARDWARE ERROR
SOLID BLUE		SD CARD INSERTED
BLINKS IN SUCCESSION		
SINGLE BLINK RED, YELLOW, AND GREEN		CUSTOMIZED SYSTEM BOOT UP
ONE (1) RED BLINK		ANTI-JAM ROUTINE
TWO (2) RED BLINKS		36 VDC OUT OF RANGE
THREE (3) RED BLINKS		MOTOR COMM ERROR
FOUR (4) RED BLINKS		CHARGE COMM ERROR
FIVE (5) RED BLINKS		BATTERY OUT OF RANGE
ONE (1) YELLOW BLINK		HIGH MOTOR CURRENT
TWO (2) YELLOW BLINKS		LOW BATTERY VOLTAGE
THREE (3) YELLOW BLINKS		TEMP OUT OF RANGE
FOUR (4) YELLOW BLINKS		5 VDC OUT OF RANG
FIVE (5) YELLOW BLINKS		GPS COMM ERROR
10 BLINKS, RED, YELLOW, AND GREEN AT ONCE		INCOMPLETE SD CARD UPDATE
ONE (1) YELLOW AND GREEN AT ONCE		GPS SATELLITE LOCK ERROR
ZAHN BOARD LED		
SOLID GREEN LIT		12 VDC ON
SOLID GREEN NOT LIT		12 VDC OFF

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Brain Board Blink Code Chart
SolarBee
867_20160921

SB10000LH FEATURES

Technology Description:	Floating, solar powered, circulation equipment for wastewater treatment and freshwater applications. Day/night operation on solar only by utilizing a battery to store excess daytime energy for nighttime operation.
Flow Rates:	*Flow rates at full speed at 10 feet (3 meter) diameter.*
Direct Flow Rate - Day	3,000 gallons per minute, (12,000 Liters per minute).
Induced Flow Rate - Day	7,000 gallons per minute. (26,000 Liters per minute).
Combined Flow Rate - Day	10,000 gallons per minute. (38,000 Liters per minute).
Combined Flow Rate - Night	10,000 gallons per minute (38,000 Liters per minute).
Machine Size/Weight:	Assembled machine is 16 feet (5m) in diameter and weighs 850 pounds (380kg).
Shipping Size/Weight:	Machine can be crated and shipped in 87 inch (2.2 m) wide X 87 inch (2.2 m) long X 65 inch (1.7 m) high X 1500 pounds (680 kg) crate and 4 feet (1.2 m) wide X 4 feet (1.2 m) long X 4 feet (1.2 m) high X 500 pound (225 kg) crate. For multiple machines and Hose lengths greater than 40 ft (6 m), different crating may apply.
Materials of Construction:	316 stainless steel construction. Foam-filled high-density polyethylene (HDPE) floats. Thermoplastic rubber intake hose. Concrete mooring blocks are encapsulated in HDPE.
Drive System:	High torque, direct drive (no gearbox), low voltage brushless D.C. motor.
Power Supply/Control System:	*PV solar panels are protected from bird fouling with bird deterrent kit.*
PV Solar Panels	3 X 80-watt photovoltaic solar panels orientated in triangular pattern. On-board battery storage for day/night operation.
Electronic Controller	Digital solid-state controller, mounted in weather-tight (NEMA 4X) enclosure with externally fused disconnect. SCADA output through RS-232 serial communication (Modbus RTU), DB9 male connection point inside enclosure. Wireless options available, not included.
Wiring	Corrosion-resistant industrial cord with molded watertight connectors that are indexed to prevent improper wiring.
Rotating Assembly:	Removable assembly with easy access to motor and digital controller. Impeller handles 4-inch (10cm) spherical solids. Oil-filled (food grade) teflon freeze sleeve with o-rings, shaft. Rotational indicator on shaft.
Flotation System:	Three floats in triangular pattern each with an adjustable float arm for proper vertical positioning, total float buoyancy of 1,450 pounds (660kg).
Floats	Each float have independence to move freely about a central pivot point on the bottom side of the float which allows the forces due to waves be applied to the floats which does not transfer to other machine components.
Float Arms	316 stainless steel heavy walled tubing provides a robust connection of the machine to the bottom pivot point of the high wave float.
Fluid Intake Assembly:	*Hose system bolted to bottom of structural assembly.*
Hose System	10 to 100 feet (3 to 30.5 meters) available in 36 inch (91cm) diameter X 10, 15, or 20 feet (3, 4.5, 6 meter) sections.
Intake Type	Horizontal high wave plate valve with 12-inch (31cm) openings. Valve releases escaping water through bottom of hose during high wave events to minimize stress on machine.
Intake Depth Adjustment	15 feet (4.5 m) of field adjustment with three SS chains connected to hose coupling.
Anchoring:	Two mooring blocks tethered together with SS chain and attached to structural member on unit.
Ice Protection:	Freeze sleeve and positive pumping under distribution dish to maintain circulation.
Minimum Operating Depth:	48-inches (1.2 m) with optional leg extensions. No damage to machine or bottom of reservoir when run dry in shallow water.
Accessories Available:	(1) Marker Light Kit
Life/Maintenance/Warranty:	Expect 25-year life, minimal maintenance. Limited 2-year parts and conditional labor warranty. Limited 25 year photovoltaic module manufacturer performance warranty and 10 year motor warranty.

Patent Pending

Subject to change without notice.

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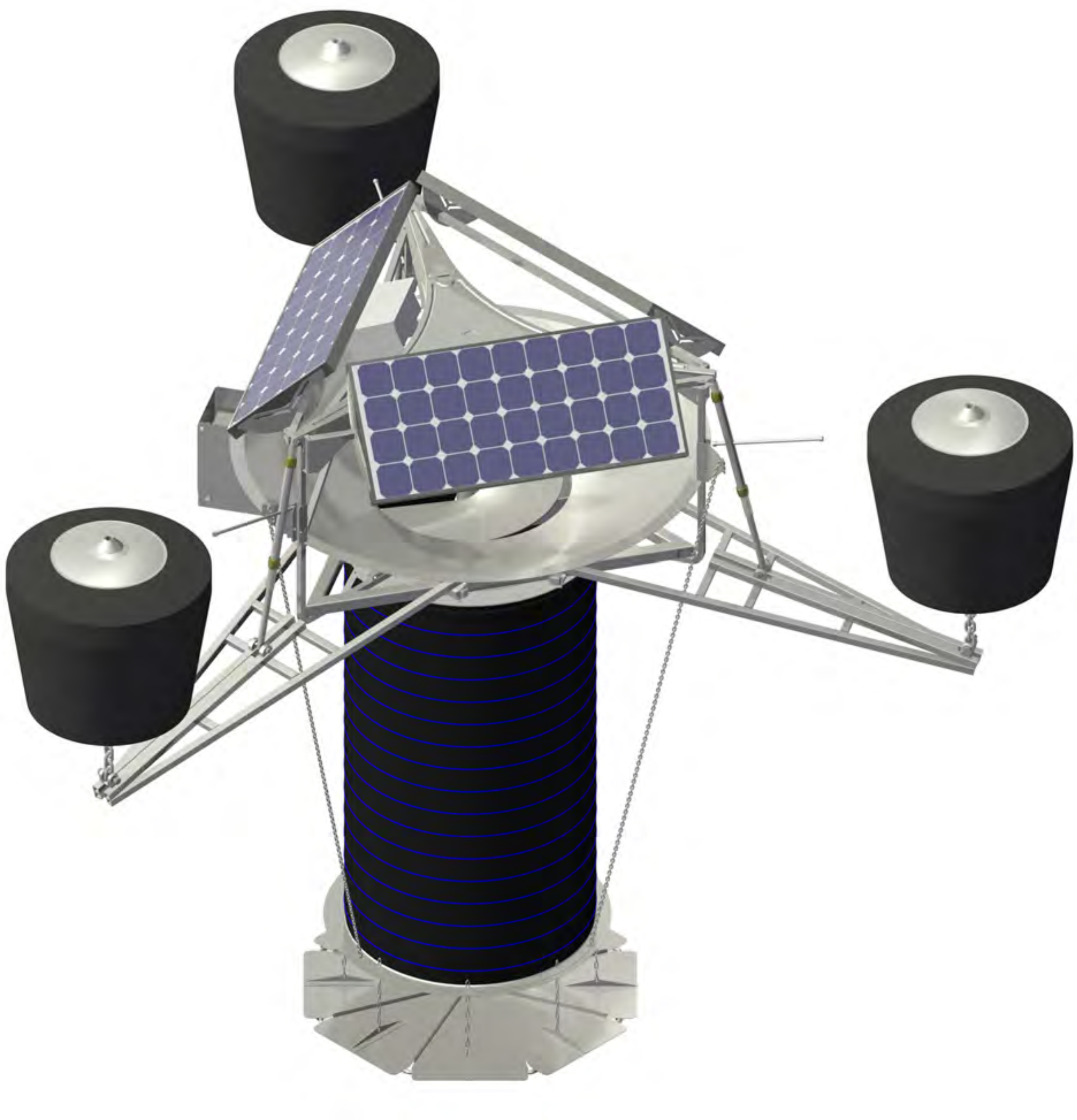
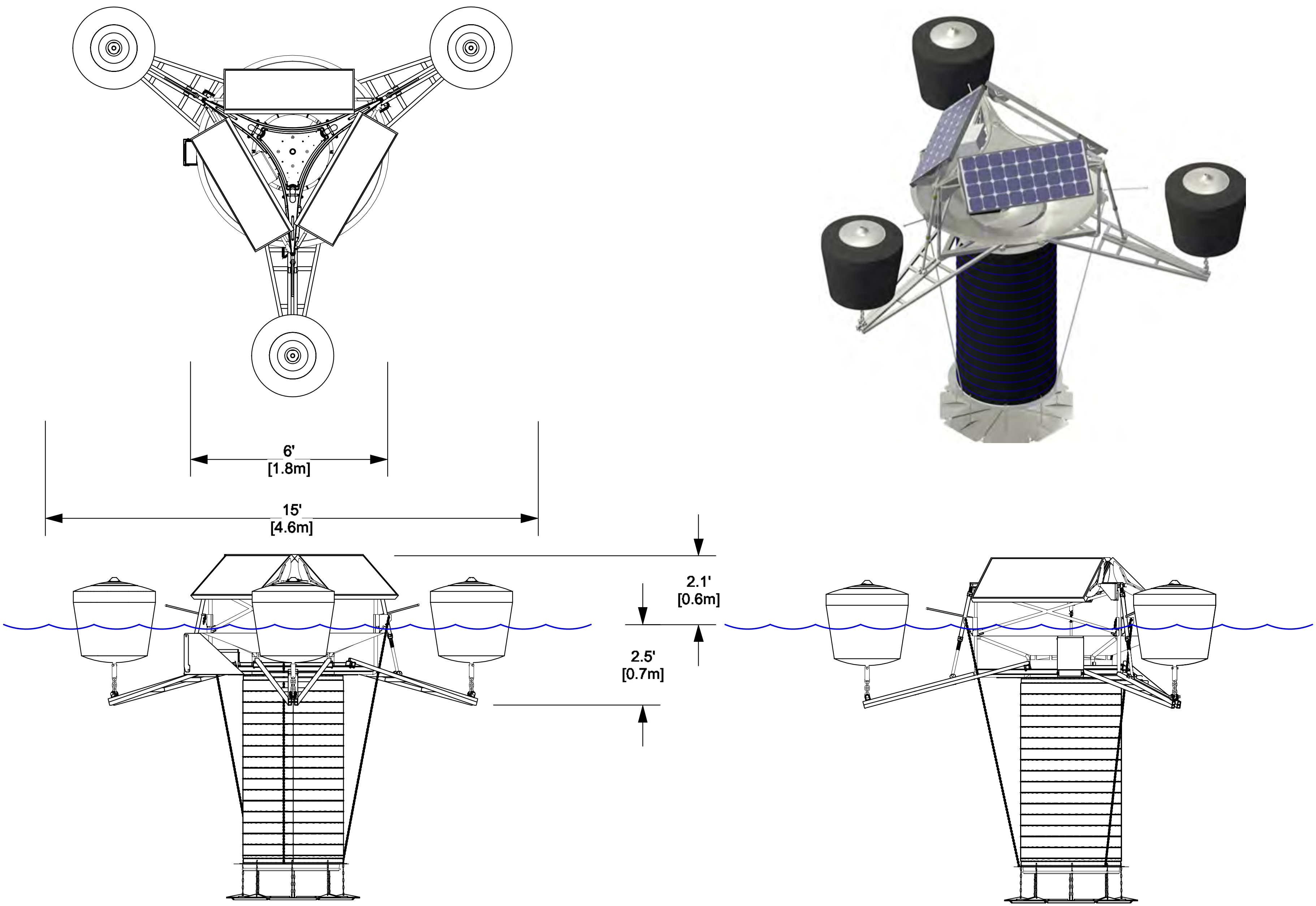
MODEL SB10000LH





MATERIAL:		PROPRIETARY AND CONFIDENTIAL	
See Specifications		THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF MEDORA CORPORATION. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF MEDORA CORPORATION IS PROHIBITED.	Medora Corporation
SCALE: 1:50	DRAWN BY: CM	TITLE: Dimension Drawing, SB10000LH	

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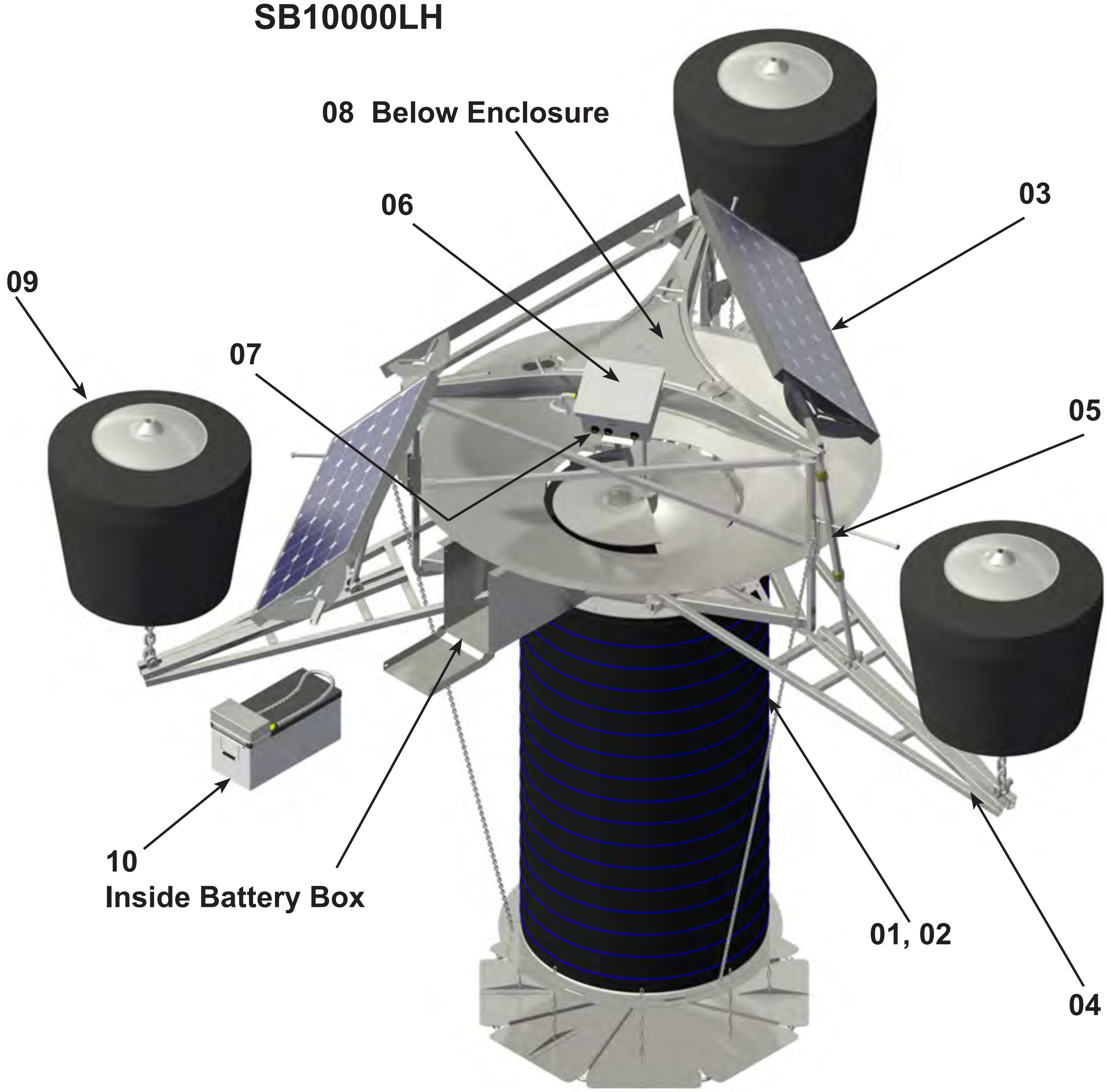
NO.	PART #	DESCRIPTION
01	22281100	ROTATING ASSEMBLY
02	22010027	LOWER COUPLING SLEEVE
03	14283095	SOLAR PANEL (WIRED)
04	18260225	FLOAT ARM ASSEMBLY
05	18265000	TURNBUCKLE ASSEMBLY
06	14300000	DIGITAL CONTROLLER
07	14013022	MOTOR CONTROL CORD
08	20504500	BRUSHLESS MOTOR
09	24010100	FLOAT
10	14285212	BATTERY

SB10000LH



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Solar SB Mixers Limited Replacement Warranty:

SolarBee SB Mixers. All new and factory-refurbished SolarBee SB mixers and circulators are warranted to be free of defective parts, materials, and workmanship for a period of two years from the date of installation. In addition, the SolarBee brushless motor is warranted for a period of ten years from the date of installation. A manufacturer's warranty exceeding this SolarBee warranty, such as photovoltaic modules (solar panels), which currently have a manufacturer's 25-year performance warranty, will be honored. This warranty is valid only for SolarBee equipment used in accordance with the owner's manual, and consistent with any initial and ongoing factory recommendations. This warranty is limited to the repair or replacement of defective components only and does not apply to normal wear and tear. If the factory's service crews performed the original on-site placement and startup, then this warranty also includes labor. Where labor is included, in lieu of sending a factory service crew to the site for minor repairs, Medora Corporation may choose to send the replacement parts to the owner postage-paid and may pay the owner a reasonable labor allowance, as determined solely by Medora, to install the parts. There is no liability for consequential damages of any type. The warranty that is submitted and provided with the purchased equipment is the valid warranty.

SolarBee SCADA and any optional accessories. These items are considered "buyout" items for Medora Corporation, and as such include a warranty against defects in material and workmanship for one year from the date of purchase. This warranty covers parts only, not labor. Parts that are determined by Medora Corporation to be defective in material or workmanship under normal use during the one year warranty period will be repaired or replaced. Shipping charges are the responsibility of the customer.

Terms applicable to all equipment. There is no liability for any consequential damages of any type, or to replace items that wear out from "normal use" in Medora's sole determination. Equipment warranties are valid only for equipment that is used in accordance with the owner's manual, and consistent with any initial and on-going factory recommendations. Medora Corp.'s warranties change from time to time; only the exact warranty in effect when the equipment was purchased, as provided with the equipment, is valid.

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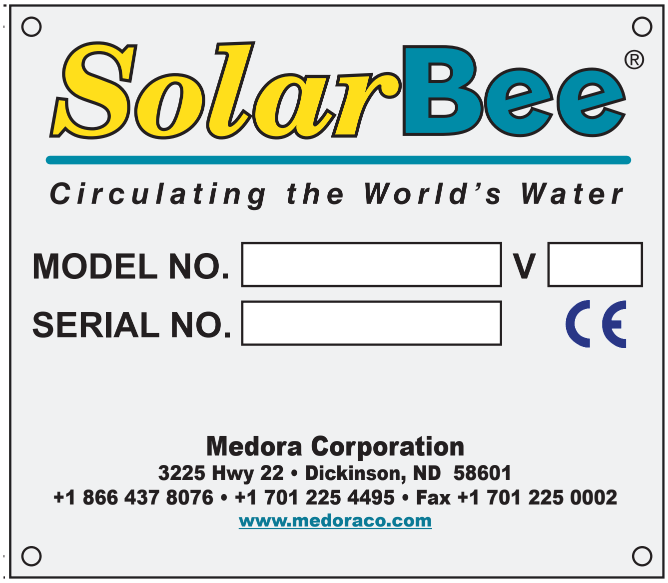
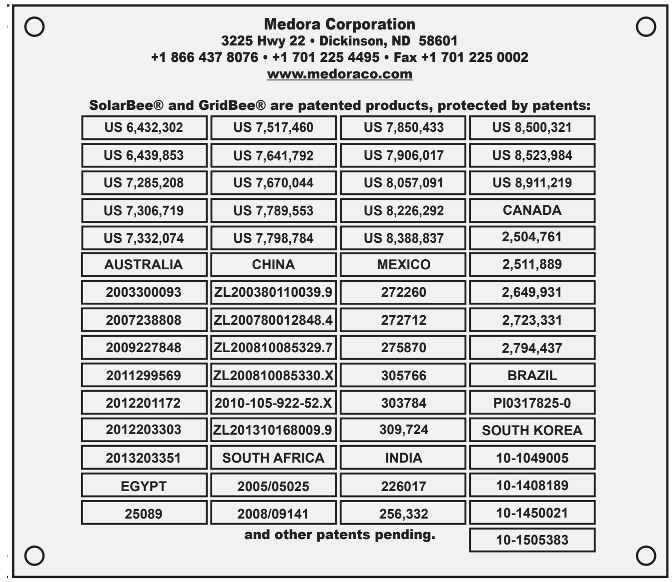
Please consult your state law regarding this warranty as certain states may have legal provisions affecting the scope of this warranty.

IN NO EVENT WILL MEDORA CORP. OR ITS AFFILIATES BE LIABLE FOR ANY DAMAGES CAUSED BY FAILURE OF BUYER TO PERFORM BUYER'S RESPONSIBILITIES OR FOR FOLLOWING MEDORA CORP. ADVICE. IN NO EVENT WILL MEDORA CORP. OR ITS AFFILIATES BE LIABLE FOR ANY LOST PROFITS OR USE OR OTHER PUNITIVE, SPECIAL, EXEMPLARY, CONSEQUENTIAL, INCIDENTAL OR INDIRECT DAMAGES, HOWEVER CAUSED, ON ANY THEORY OF LIABILITY, WHETHER OR NOT MEDORA CORP. HAS BEEN ADVISED OF SUCH DAMAGES, OR REASONABLY COULD HAVE FORESEEN THE POSSIBILITY OF SUCH DAMAGES, OR FOR ANY CLAIM AGAINST BUYER BY ANOTHER PARTY.





US 6,432,302	US 7,517,460	US 7,850,433	US 8,500,321
US 6,439,853	US 7,641,792	US 7,906,017	US 8,523,984
US 7,285,208	US 7,670,044	US 8,057,091	US 8,911,219
US 7,306,719	US 7,789,553	US 8,226,292	CANADA
US 7,332,074	US 7,798,784	US 8,388,837	2,504,761
AUSTRALIA	CHINA	MEXICO	2,511,889
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2007238808	ZL200780012848.4	272712	2,723,331
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2011299569	ZL200810085330.X	305766	BRAZIL
2012201172	2010-105-922-52.X	303784	PI0317825-0
2012203303	ZL201310168009.9	309,724	SOUTH KOREA
2013203351	SOUTH AFRICA	INDIA	10-1049005
EGYPT	2005/05025	226017	10-1408189
25089	2008/09141	256,332	10-1450021
			10-1505383

and other patents pending.

Identify all possible hazards. Determine what safeguards are needed and implement them. **Only you, the user,** understand your product and system characteristics fully. ***The ultimate responsibility for safety is with you. Your safety ultimately rests in your hands.*** Do your part and you will enjoy safe, trouble free operation for years to come.

SolarBee Removal

If temporary removal of the SolarBee from the water body is required, please carefully read and follow the instructions in this section.

Towing SolarBee Using Small Boat

TOOLS / EQUIPMENT REQUIRED:

- Small Boat with 3+ HP Motor
- 25 ft (7.5 m) Tow Strap/Rope
- Crane, Back Hoe, or other equipment capable of reaching out into the water and hoisting 2000 lb (900 kg).
- 3 point lifting chain/strap, 2000 lb (900 kg) capacity.
- Metric Socket and Wrench Set (Sizes 10mm, 13mm, 19mm, & 24mm Required)
- Pliers

Hoisting SolarBee Out Of Water

JOB OUTLINE:

1) Locate Removal and Staging Area

2) Prepare SolarBee for Towing

3) Tow SolarBee to Removal Zone

4) Hoist SolarBee from Water

5) Disassembly of Major Components

Staging Area With Disassembled SolarBee Units

JOB PERSONNEL AND DURATION:

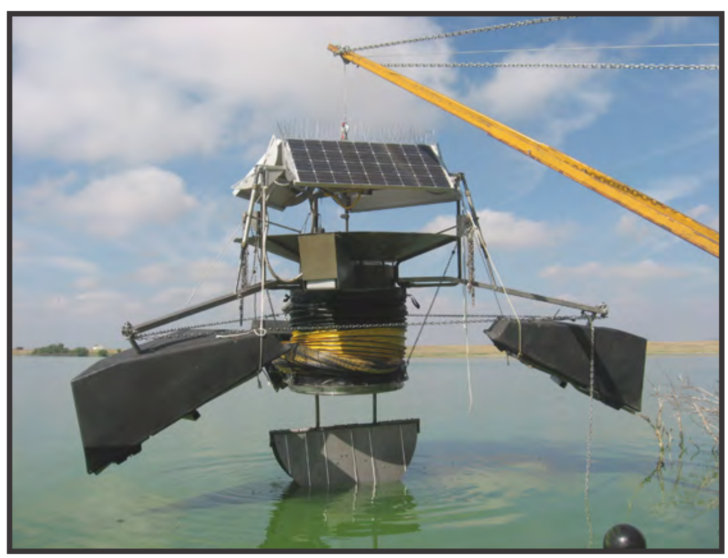
Removal of 1 SolarBee unit will require approximately 4 to 6 hours with 2 to 3 workers. For large water bodies with long distances to tow the SolarBee unit, allow for additional time and favorable weather conditions.

1. Locate Removal and Staging Area

The first step in removing the SolarBee from a water body is to find a good location to, 1) tow the SolarBee to, 2) hoist it out of the water, and 3) disassemble it into its major componets for transportation and storage.

The following considerations should be made when choosing a removal and staging area:

- Crane or Hoist Equipment Access to Water
- 4 ft (120cm) Water Depth within Crane/Hoist Reach
- Close proximity to SolarBee locations
- 20 ft X 20 ft (6 m X 6 m) Disassembly Space per SolarBee Unit.



2. Prepare SolarBee for Towing

TOOLS: Pliers, 13mm socket & wrench

Once a location has been chosen for towing the SolarBee to, the next step is to go out to the SolarBee and prepare it for towing. The following steps need to be followed before towing the SolarBee:

STEP 1: Turn the machine off and adjust the hose all the way up as far as it can be pulled up. Be sure to follow correct hose adjustment procedure.

STEP 2: Extend all three turnbuckles all the way out to raise the machine out of the water as much as possible.

DECISION: Can anchor be left in place? If Yes, it is suggested that a 15 lb (60 N) bouyant float ball be connected to the anchor chain to maintain proper positioning when the SolarBee is re-installed. GPS technology can be used to mark position if anchoring or tethering removal is required.

STEP 3: If removing anchors, pull up anchors at this time. If leaving anchors in place, disregard this step.

STEP 4: Locate the chain that connects the SolarBee float arm to the anchors and disconnect at a quick link or swivel using pliers or wrenches, whichever is applicable.

STEP 5: If the SolarBee contains leg extensions, these should be removed.

NOTE: The tow rope or strap should be connected to the same point where the anchor chain attaces to. The SolarBee is now ready to be towed.

Raising Hose Up Tight

Anchor Chain Connection Point (At Float Ball)

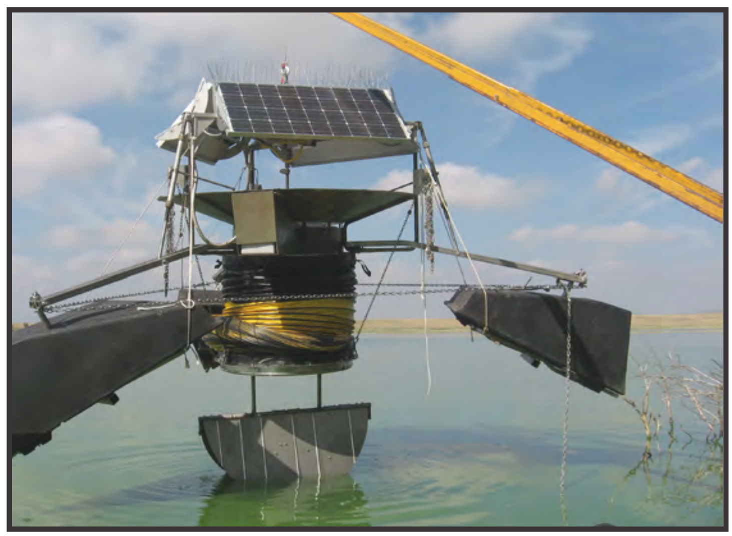
SolarBee in Raised Position, Ready to Tow

3. Tow SolarBee to Removal Area

TOOLS: Boat and Boat Motor, Tow Strap/Rope

Towing the SolarBee can be done using several methods, however it is very important to tow slowly, preventing damage to the SolarBee.

One method is to hook a towing strap or rope around one of the float arms at the anchor connection point and pull the SolarBee with a boat.



Another method is to push the SolarBee using the front of the boat. This works the best with a small sized boat. It is important that extra caution be taken not to push in between float arms and not on a solar panel. Push on a solid structure, such as the under side of the distribution dish if using this method.

IMPORTANT: TO PREVENT INJURY AND COSTLY DAMAGE TO THE MACHINE, DO NOT EXCEED 5 MPH (8KM/HR) WHEN TOWING OR PUSHING A SOLARBEE.

Position the SolarBee at the pond edge where it can be reached by the crane or hoist equipment. The SolarBee will float in approximately 4 ft (120 cm) of water.

4. Hoist SolarBee From Water

TOOLS: Crane, Backhoe, or Hoist;
3-Point Lifting Chain/Strap

Now that the SolarBee is at the pond edge where it can be reached, it is ready to be hoisted out of the water.

The following steps need to be followed when removing the SolarBee from the water:

STEP 1: Connect the 3-Point Lifting Chain or Strap to all 3 lifting points on the top frame of the SolarBee. Be sure all points are securely attached.

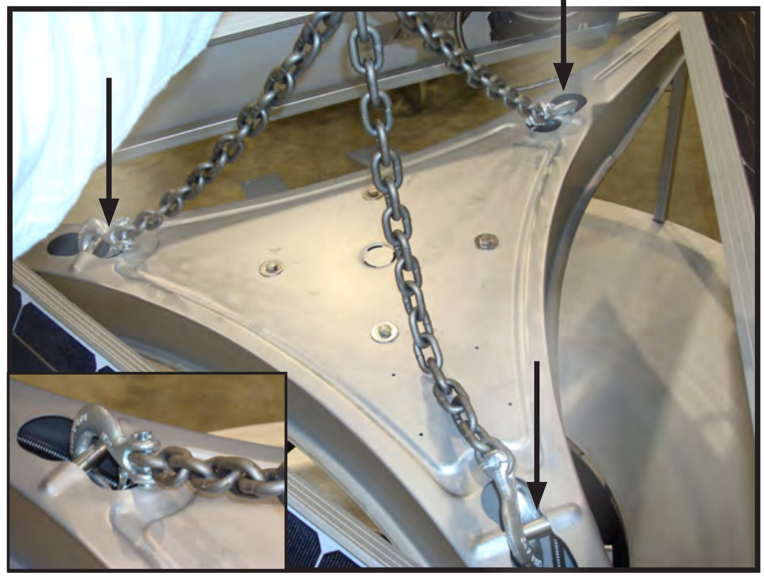
STEP 2: Position the crane, back hoe, or hoisting equipment where it can safely reach and vertically hoist the SolarBee.

STEP 3: Connect to the 3-Point Lifting Chain or Strap and be sure everyone is clear of the lifting zone.

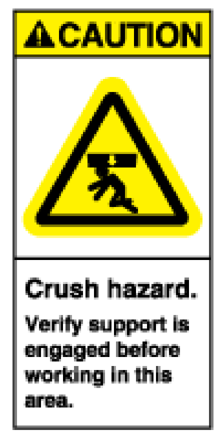
STEP 4: Hoist the SolarBee out of the water and pull up on a flat working surface.

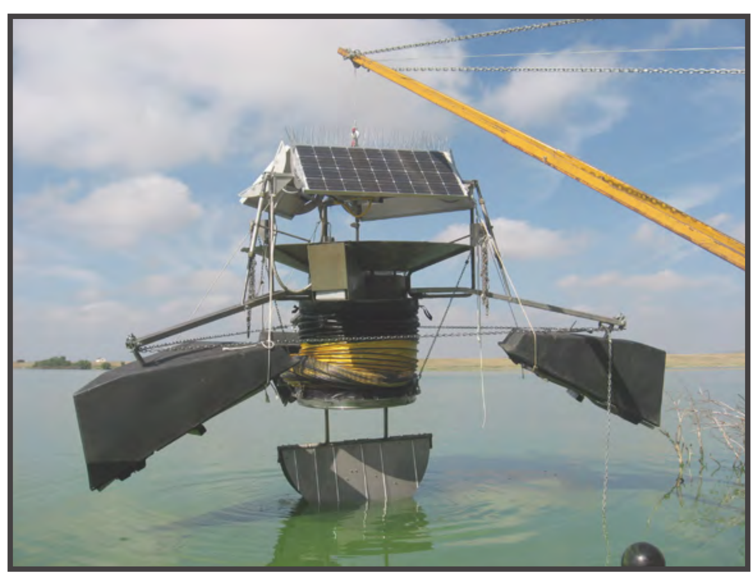
STEP 5: Lower the SolarBee until the intake plate is close to touching the ground. Be sure not to lower the machine too much to crush the intake plate. Utilize blocks or keep the machine safely suspended for disassembly.

The SolarBee is now ready to be disassembled.



CAUTION: WHILE SOLARBEE IS SUSPENDED IN THE AIR, KEEP CLEAR BELOW AND IMMEDIATELY AROUND SOLARBEE TO AVOID BEING CRUSHED IN THE EVENT OF THE UNIT UNEXPECTEDLY DROPPING TO THE GROUND . FAILURE TO FOLLOW THIS WARNING COULD LEAD TO SERIOUS INJURY!





5. Disassembly Of Major Components

TOOLS:
Metric Socket and Wrench Set (10mm, 13mm, 19mm, and 24mm)
Marker (Sharpie)

Once the SolarBee is on shore, it is ready for disassembly to make it ready to store or transport.

STEP 1: Disconnect the three depth indicator chains from the chain brackets and remove the hose from below the dish.

STEP 2: Remove the intake plate from the hose.

STEP 3: Once the hose is removed, turn in the turnbuckles until the core unit rests on the ground and the float arms and turnbuckles are not in compression or tension.

STEP 4: Remove the turnbuckles from the core unit.

STEP 5: Remove the floats from the float arms.

STEP 6: Using a marker, place an indicator mark next to the hole that is used to bolt the float arm to the lower part of the core unit. This will aid when reinstalling the machine.

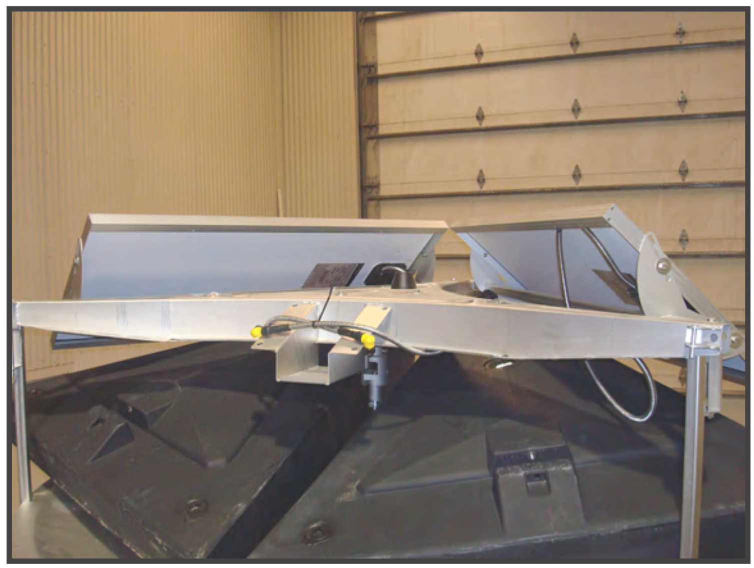
STEP 7: Remove the float arms from the machine.

SolarBee Storage

Transporting and Storage
SPACE: 8 ft X 10 ft (2.5 m X 3 m) per Unit
TOOLS: Crane, Backhoe, or Hoist;
3-Point Lifting Chain/Strap

Now that the SolarBee is disassembled, the following procedures will help to make the SolarBee compact for transporting and storage.

The SolarBee components should all be kept together and organized to avoid missing parts when reinstalling. The SolarBee can be stored outside if necessary.



TIP 1: Open the two panel gates not covering the digital controller and place two floats within the core unit as shown in the photo. Close up the panel gates. One float will have to be stored separately

TIP 2: Stack the float arms on top of one another to minimize space.

TIP 3: Keep the hose away from sharp objects or corners that may be abrasive during storage or tranporation.

TIP 4: Place all small hardware and components in a container with a lid.

TIP 5: Follow the instructions on the next page to preserve the battery and electronics during storage.

IMPORTANT: ALWAYS USE A 3-POINT LIFTING CHAIN TO HOIST THE SOLARBEE UNIT.

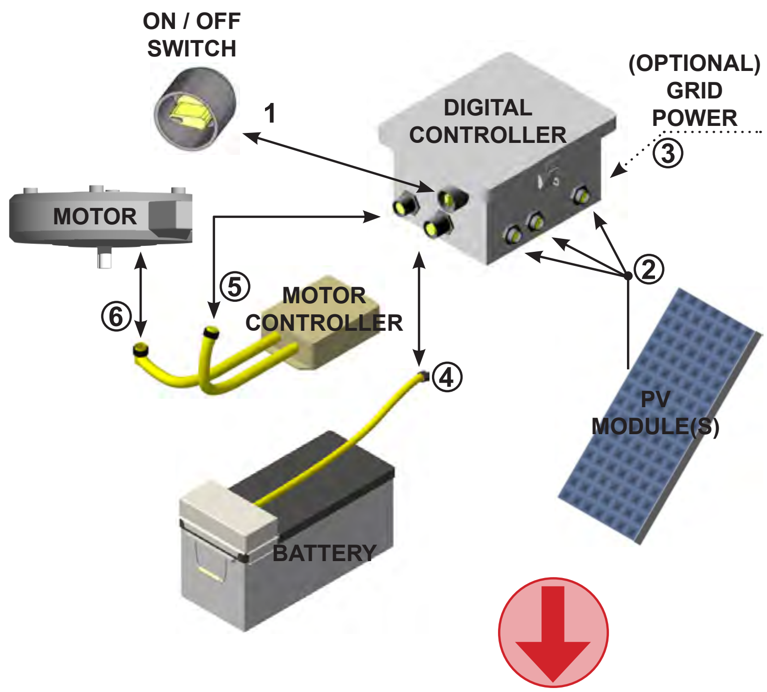
Battery and Electronics Care

If the SolarBee is removed or stored, there are several guidelines to follow for maintaining a healthy battery charge. Following these guidelines will result in the SolarBee being ready to operate when re-installed :

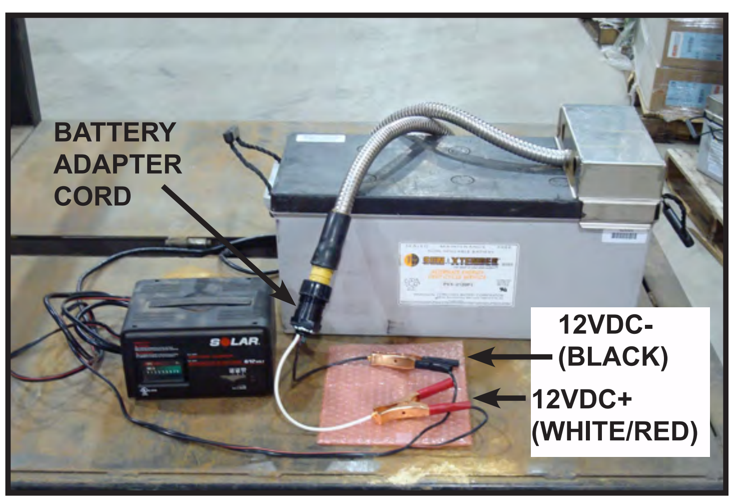
SHELTERED OR SHADED STORAGE:
If you plan to store the SolarBee unit where there is limited or no sunlight hitting the solar panels, follow these steps:
1) Disconnect the battery cord and solar panel cords from the outside panels of the digital controller.
2) Using a 12VDC battery charger and special battery cord adapter (request from SolarBee Customer Service 1-800-437-8076), charge the battery at a rate of 8 Amps or less until fully charged. Repeat this charging once every two months and just prior to re-installing the machine in the spring.

UNSHELTERED OR UNSHADED STORAGE:
If you plan to store the Solarbee unit where it will receive sunlight on the solar panels, follow these steps:
1) Turn the SolarBee off and leave solar panels and battery plugged into the digital controller.
2) Keep solar panels clear of snow or dust at least once every two weeks.

Power Down Order



WARNING: ONCE BATTERY IS CONNECTED TO BATTERY ADAPTER CORD, DO NOT ALLOW WHITE AND BLACK CONTACTS TO TOUCH ONE ANOTHER OR IT WILL RESULT IN A DEAD BATTERY SHORT AND SPARKS WILL BE EMITTED. USE EXTRA CAUTION TO PREVENT A DEAD SHORT WITH BATTERY OR CHARGER.



12 VDC Battery Charge Setup

SolarBee Installation

When re-installing your SolarBee, please carefully read and follow the instructions in this section.

TOOLS / EQUIPMENT REQUIRED:

• Small Boat with 3+ HP Motor

• 25 ft (7.5 m) Tow Strap/Rope

• Crane, Back Hoe, or other equipment capable of reaching out into the water and hoisting 2000 lb (900 kg).

• 3 point lifting chain/strap, 2000 lb (900 kg) capacity.

• Metric Socket and Wrench Set (Sizes 10mm, 13mm and 19mm Required)

• Pliers

Towing SolarBee Using Small Boat

Hoisting SolarBee Out Of Water

Staging Area With Disassembled SolarBee Units

JOB OUTLINE:

1) Locate Staging and Deployment Area

2) Assembly of Major Components

3) Deploy and Float SolarBee

4) Tow SolarBee Into Final Position

5) Final Settings

JOB PERSONNEL AND DURATION:

Installation of 1 SolarBee unit will require approximately 4 to 6 hours with 2 to 3 workers. For large water bodies with long distances to tow the SolarBee unit, allow for additional time and favorable weather conditions.

1. Locate Staging & Deployment Area

The first step to installing the SolarBee into a water body is finding a good location to, 1) unload major components, 2) lowering SolarBee into the water, and 3) towing into position from

The following considerations should be made when choosing a staging and deployment area:

- Crane or Hoist Equipment Access to Water
- 2 ft (60cm) Water Depth within Crane/Hoist Reach
- Close proximity to SolarBee locations
- 20 ft X 20 ft (6 m X 6 m) Assembly Space per SolarBee Unit.

2. Assembly Of Major Components

TOOLS:
Metric Socket and Wrench Set (10mm, 13mm, & 19mm)
Anti Sieze (Apply small amount on all threaded fasteners and turnbuckles when assembling)

With all major components nearby and battery in place on the core unit, the SolarBee is ready for final assembly.

STEP 1: Connect the float arms to the lower part of the core unit using the M12 stainless steel bolts and locking nuts. Be sure to use the proper hole in the mount block for all three float arms. For hoses shorter than 15 ft (4.5 m), use the front hole, othewise use back hole.

STEP 2: Using the float pins, attach the floats and float plates to the float arm (2 pins per float).

STEP 3: Attach the turnbuckles to connect the core unit to the float arm. IMPORTANT: Prior to connecting turnbuckles be sure that both ends are turned all the way in to achieve full extension.

STEP 4: Once both ends are attached, turn out the turnbuckles out all the way to suspended the bottom of the core unit in the air.

STEP 5: Attach the intake plate to the bottom of the hose. The bottom of the hose contains the three weld links which the indicator chain attaches to.

STEP 6: Slide the hose and intake beneath the core unit and attach the depth indicator chains into the chain bracket by the #4 or #5 depth indicators. With the flanges properly aligning, connect the hose flange to the core unit using eight M8 bolts and locking nuts.

3. Deploy and Float SolarBee

TOOLS: Crane, Backhoe, or Hoist;
3-Point Lifting Chain/Strap

Now that the SolarBee is fully assembled, it is ready to be hoisted into the water.

The following steps need to be followed when lowering the SolarBee into the water:

STEP 1: Connect the 3-Point Lifting Chain or Strap to all 3 lifting points on the top frame of the SolarBee. Be sure all points are securely attached.

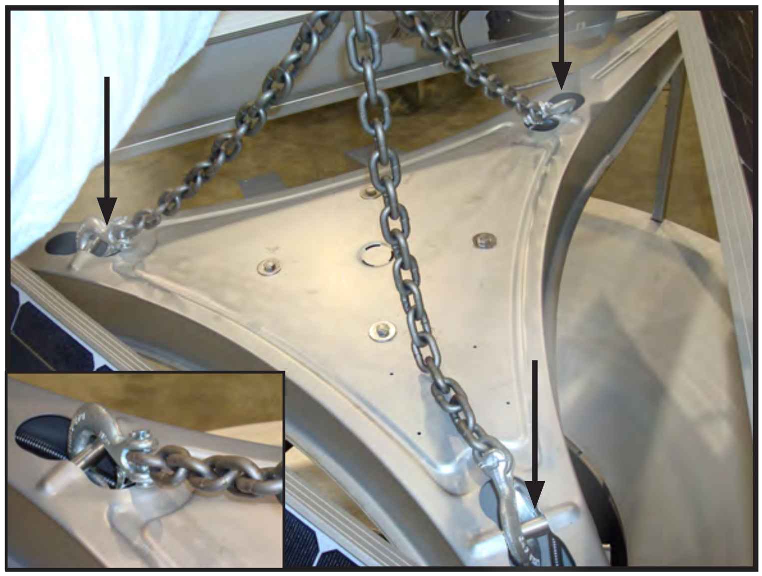
STEP 2: Position the crane, back hoe, or hoisting equipment where it can safely reach and vertically hoist the SolarBee.

STEP 3: Connect to the 3-Point Lifting Chain or Strap and be sure everyone is clear of the lifting zone.

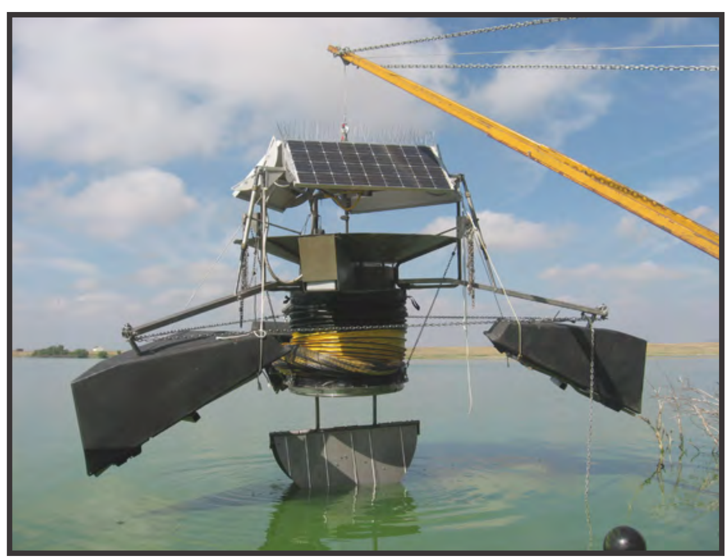
STEP 4: Hoist the SolarBee, back it over the water, and lower it into the water so that it is floating on its own.

STEP 5: Disconnect the 3-Point Lifting Chain or Strap

The SolarBee is now ready to be towed into place.



CAUTION: WHILE SOLARBEE IS SUSPENDED IN THE AIR, KEEP CLEAR BELOW AND IMMEDIATELY AROUND SOLARBEE TO AVOID BEING CRUSHED IN THE EVENT OF THE UNIT UNEXPECTEDLY DROPPING TO THE GROUND . FAILURE TO FOLLOW THIS WARNING COULD LEAD TO SERIOUS INJURY!



4. Tow SolarBee Into Final Position

TOOLS: Boat and Boat Motor, Tow Strap/Rope

Towing the SolarBee can be done using several methods, however it is very important to tow slowly, preventing damage to the SolarBee.

One method is to hook a towing strap or rope around one of the float arms at the anchor connection point and pull the SolarBee with a boat.

Another method is to push the SolarBee using the front of the boat. This works the best with a small sized boat. It is important that extra caution be taken not to push in between float arms and not on a solar panel. Push on a solid structure, such as the under side of the distribution dish if using this method.

IMPORTANT: TO PREVENT INJURY AND COSTLY DAMAGE TO THE MACHINE, DO NOT EXCEED 5 MPH (8KM/HR) WHEN TOWING OR PUSHING A SOLARBEE.

The SolarBee will float in approximately 4 ft (120 cm) of water. Tow the unit out to the anchor.

5. Final Settings

TOOLS: Pliers, 13mm socket & wrench

Once the SolarBee is in final position, the last step is to properly set and start it.

STEP 1: Connect the SolarBee unit to the mooring block anchors. Utilize the float ball as shown in the photo as the tie off point(s) to the anchor system.

STEP 2: Using the proper hose setting procedure, adjust the hose/intake into correct position by slowly and evenly lowering the depth indicator chains.

STEP 3: Using the correct startup order, power up the SolarBee unit.

STEP 4: If the SolarBee contains leg extensions, add these at this time.

STEP 5: Adjust all turnbuckles to achieve the proper distribuition dish depth setting.

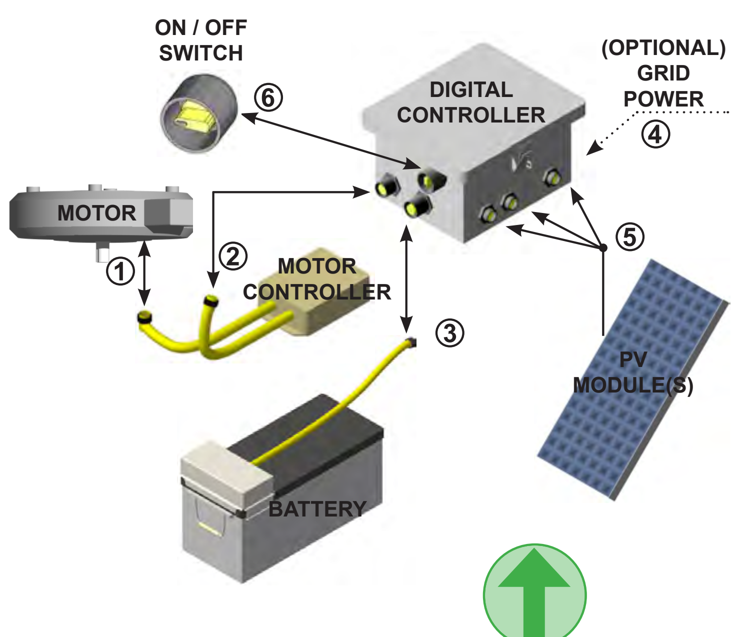
STEP 6: Do a rotational speed check.

The SolarBee should now be completely operational. If you have questions or concerns about it being properly installed, please contact SolarBee Customer Service at **(866) 437-8076 or customerservice@ solarbee.com**

Anchor Chain Connection Point (At Float Ball)

Final Adjustments to Machine

Power Up Order



SolarBee Installation, Storage, and Removal

SolarBee, Inc. employs a full staff of highly qualified Service and Installation Technicians certified to perform the tasks required to install or remove SolarBee circulation equipment in potable water tanks and reservoirs.

SolarBee's specialized Service and Installation Technicians are trained in Confined Space, Fall Protection, and other related subjects as required by OSHA to perform the necessary work to install or remove SolarBee equipment.

If you need to remove your SolarBee circulation equipment from your tank or reservoir, please contact SolarBee's Customer Service Department at:

+1 866 437 8076

Upper Red Rock Lake, MT:

Preliminary Engineering and Feasibility Analysis to Improve Winter Habitat for Arctic Grayling

Alternative 2 (Option A)- HDPE Piping and Inlet structures

Material Estimates	Quantity	Unit Cost ($)	Cost ($)	Source or Assumption
Pipe Bedding Delivered and Installed (Ton)	4,500	$ 9	$ 39,000	Estimated based on project of similar nature
8" HDPE SDR 17 (FT)	1,800	$ 24	$ 43,200	Based on CDM Smith OPCC for project of similar nature
18" HDPE SDR 17 (FT)	2,700	$ 30	$ 81,000	Based on CDM Smith OPCC for project of similar nature
Concrete Inlets (EA)	2	$ 6,000	$ 12,000	Estimated based on project of similar nature
Installation (LS)	1	$ 19,868	$ 19,868	Prevailing wage rates for 3 man crew of pipefitter, equipment operator, laborer + estimated contractor GC, taxes, markup
Equipment | ODCs	1	41,552	$ 41,552	See below
Contingency (10%)			$ 23,662	
Total			**$ 260,282**	

Labor Estimates	Hours	Hourly Rate ($)	Cost ($)	Source
Install 8" HDPE w/ Concrete Inlet	150	$ 51	$ 7,641.50	Hourly rate is composite average of 3 man crew. Wage rates from montana prevailing rates for pipefitter, operator, laborer + estimated contractor GC, taxes, markup
Install 18" HDPE w/ Concrete Inlet	240	$ 51	$ 12,226.40	Hourly rate is composite average of 3 man crew. Wage rates from montana prevailing rates for pipefitter, operator, laborer + estimated contractor GC, taxes, markup
Labor total	390	$ 51	$ 19,867.90	

Equipment | ODCs	Days	Daily Rate ($)	Cost ($)	Assumption
Excavator	49	$ 696	$ 34,104	Daily rates based on united rentals daily quote + estimated contractor GC, taxes, markup
Plate Compactor	49	$ 96	$ 4,704	Daily rates based on united rentals daily quote + estimated contractor GC, taxes, markup
Dewatering Pump	49	$ 56	$ 2,744	Daily rates based on united rentals daily quote + estimated contractor GC, taxes, markup
Equipment | ODC Ttotal			$ 41,552	

Upper Red Rock Lake, MT:

Preliminary Engineering and Feasibility Analysis to Improve Winter Habitat for Arctic Grayling

Alternative 3 - Hydraulic Dredging and Island Construction

Material Estimates	Quantity	Unit Cost ($)	Cost ($)	Source or Assumption
Cristifoli SD-110 fuel	315,000	$ 0.4	$ 126,000	vendor quote
Geotextile Tube	7,000	$ 152	$ 1,066,800	https://www.cee.msstate.edu/assets/documents/(2009)%20SERRI%20Report%2070015-002%20(Geotextile%20Tubes%20Workshop).pdf
Dredging (labor)	6,840	$ 48	$ 326,268	Contract labor at $160/hr (4 man crew for construction installation)
Equipment | ODCs	1	$ 594,000	$ 594,000	
Contingency (10%)			$ 211,307	
Total			**$ 2,324,375**	

Labor Estimates	Hours	Hourly Rate ($)	Cost ($)	Assumption
Operator	6840	$ 48	$ 326,268	operator + estimated contractor GC, taxes, markup
			$ -	
			$ -	
			$ 326,268	

Equipment | ODCs	Months	Monthly Rate ($)	Cost ($)	Assumption
Cristifoli SD-110	28.5	$ 20,000	$ 570,000	vendor quote; 11,000 CY /month
Mobilization	1	$ 24,000	$ 24,000	
			$ -	
Equipment | ODC Ttotal			$ 594,000	

$ 3.32 CY

Winston,

1. How many yards of material will the SD-110 dredge move per week/month on average?
   - It depends on where you will be discharging (distance, elevation) and material. With 750' of discharge distance and 20' of elevation I would estimate about 9,000-11,000 cubic yards per month (200 hours per month) of solids.
2. An estimated cost range per cubic yard for the machine.
   - There are a lot of variables. Costs for the dredge (not counting dewatering) if you look at a standard rental w/ 300' of pipe and average fuel costs right now, about $2.75-$3.00 per cubic yard. This is just to run the machine, no labor, land pipe, dewatering, etc..
3. Additional costs to be expected.
   - Labor fees, land pipe, permits, dewatering process (trucking, geo-bags, equipment fees, fuel fees, etc..).

In regards to the rental, below you will find what a rental for this dredge would look like:

$24,000 - Initial month rent (includes dredge and 305' of floating discharge pipe)
$ 132 - Additional pipe (price is per 20' of pipe)
$11,000 - Damage deposit (refundable upon return minus any damages or repairs needed)
$ X,XXX - Round trip freight (Glendive, MT – jobsite)

If you will be moving into a 2nd month of rental we will discount rental rates with subsequent months dropping to $20,000 per month. Also, keep in mind that as part of our rental program we do provide two days on-site with a factory technician who will oversee installation and provide operator training.

Hopefully this answers your questions, please let me know if there is anything else I can be of assistance with.

Best regards,

TROY FERCHO
Sales Manager **Direct:** 406.377.6170
Cell: 612.419.9312 **Office:** 888.817.7011

CRISAFULLI
Sludge Removal Systems

SD-110

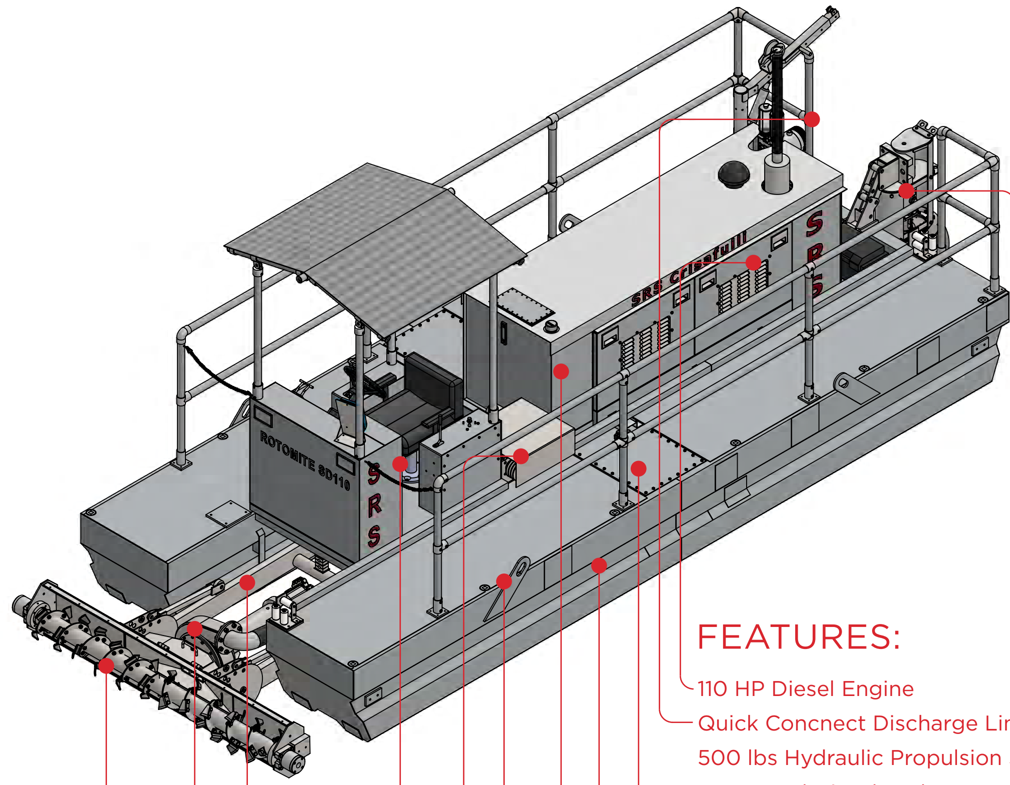
Rotomite

DIESEL POWERED
MANNED
DREDGING SYSTEM

Rely on the Diesel Powered 110 HP **SD-110** for safe, easy removal of sediment.

- The aluminum **SD-110** weighs 9,000 lbs, and is the lightest manned Crisafulli Dredge. Perfect for contractors who need to get it in and out of ponds regularly.
- The **SD-110** is self-propelled, which allows it to maneuver around obstacles, and dredge irregular areas without a cable system.

EASY TO TRANSPORT
SENSIBLY PRICED
INCOMPARABLE PERFORMANCE



FEATURES:

110 HP Diesel Engine
Quick Concnect Discharge Line
500 lbs Hydraulic Propulsion System
Integrated Diesel Tanks
12 Hour Operation Time
Foam Filled Aluminum Pontoons
Hydraulic Reservoir
4 Point Lift System
Optional Traverse Winch
Operator station
w/ Optional Encloser
12' Dredge Depth
4" Pump
1,000 GPM 70' TDH
Dual Drive Cobra Cutterhead
11,000 in LBS Torque

1.800.442.7867
srsc@crisafulli.com
crisafullipumps.com

Customer Testominal

"We appreciate the job that Larry and Nick did while they were here. They were extremely helpful, answered every question we threw at them, and were a great asset in commissioning the dredge. We appreciated their helpfulness and the job they did. I also appreciate the help that you gave us along the way. You answered multiple questions since we ordered and received the dredge 2 years ago. I have never run into customer service equal that of Crisafulli. You have all done a great job, and keep up the good work!! Thanks again!"

Jeff McGriff, Project Engineer, Lion Oil Refinery 2010

SD-110	SEVERE DUTY 4-INCH
Length (Overall)	25 Feet (7.62 M)
Length Pontoons	20 Feet (6.09 M)
Width	8.5 Feet (2.59 M)
Engine HP (Continuous)	110 HP
Fuel Capacity (Diesel)	70 US Gallons (265 Liters)
Fuel Consumption (Maximum)	6.2 Gallons Per Hour
Cutterhead Width	8.5 Feet (2.59 M)
Cutterhead Torque	11,000 Inch Pounds (1254 NM)
Cutterhead Rotation	Birotational
Cutting Teeth	Hardened Steel
Excavation Depth	0 to 12 Feet (0 to 3.66 M)
Excavation Speed	0 to 15 Feet Per Minute
Pump/Dredge Discharge	4" x 6"
Pontoons	Foam Filled, 1/8 Inch Aluminum
Depth Control	Dual Hydraulic Cylinders
Weight	9,000 lbs (4,082 Kg)
Draft	18 Inches (46 CM)
Pump Flow Rate	1,400 GPM in water
Instrumentation	Tachometer, Engine oil pressure, Engine temperature, hour meter, Hydraulic pressure, volt meter, Digital depth indicator, Hydraulic oil level & temperature

Appendix D

Alternative Drawings

CDM Smith

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: W. PARKER
DRAWN BY: W. PARKER
SHEET CHK'D BY: K. FLYNN
CROSS CHK'D BY:
APPROVED BY:
DATE: APRIL 2019

CDM Smith
560 N Park Ave #300
Helena, MT, 59601
Tel: (406) 441-1400

1/2" = 1000'
500 0 1000

UPPER RED ROCK LAKE, MONTANA:

PRELIMINARY ENGINEERING AND FEASIBILITY ANALYSIS TO IMPROVE WINTER HABITAT FOR ARCTIC GRAYLING

N

DRAFT ALTERNATIVE 1 - SOLAR
SOLARBEE MIXER

PROJECT NO. FWP #33815A
FILE NAME: ------
SHEET NO.
A-1

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: W. PARKER
DRAWN BY: W. PARKER
SHEET CHK'D BY: K. FLYNN
CROSS CHK'D BY:
APPROVED BY:
DATE: APRIL 2019

CDM Smith
560 N Park Ave #300
Helena, MT, 59601
Tel: (406) 441-1400

1/2" = 1000'
500 0 1000

UPPER RED ROCK LAKE, MONTANA:

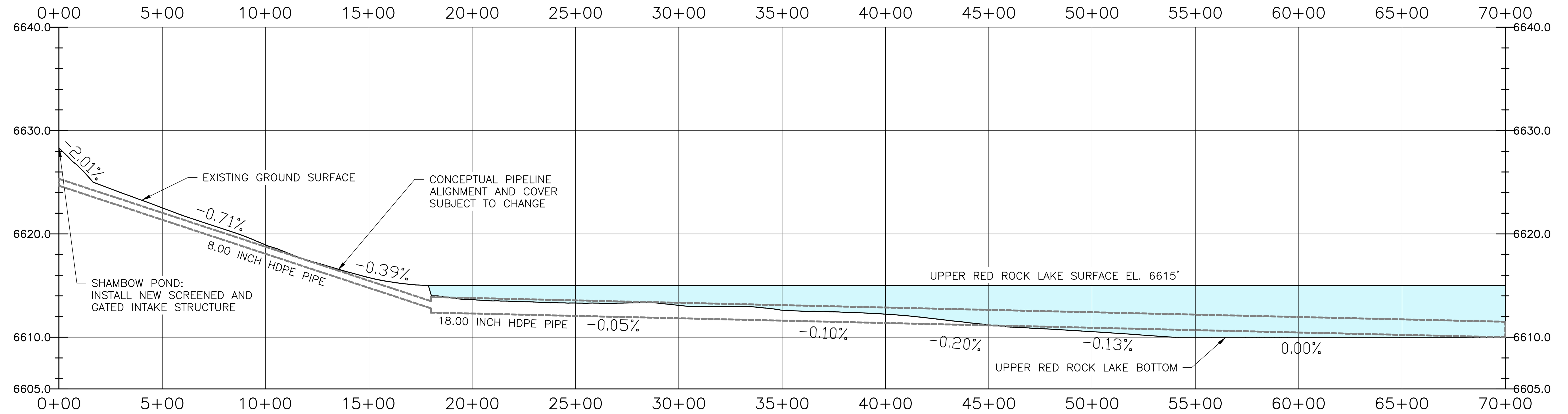
PRELIMINARY ENGINEERING AND FEASIBILITY ANALYSIS TO IMPROVE WINTER HABITAT FOR ARCTIC GRAYLING

N

DRAFT ALTERNATIVE 2 - TRIBUTARY DIVERSION AND POINT OF INFLOW MODIFICATION

PROJECT NO. FWP #33815A
FILE NAME: ------
SHEET NO.
A-2

CONCEPTUAL SHAMBOW INLET PIPELINE GRADE PROFILE: 0+00 – 70+00



CONCEPTUAL WIDGEON INLET PIPELINE GRADE PROFILE: 0+00 – 105+00

CONCEPTUAL WIDGEON INLET PIPELINE GRADE PROFILE: 105+00 – 209+90

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: W. PARKER
DRAWN BY: W. PARKER
SHEET CHK'D BY: K. FLYNN
CROSS CHK'D BY:
APPROVED BY:
DATE: APRIL 2019

CDM Smith
560 N Park Ave #300
Helena, MT, 59601
Tel: (406) 441-1400

UPPER RED ROCK LAKE, MONTANA:
PRELIMINARY ENGINEERING AND FEASIBILITY ANALYSIS TO IMPROVE WINTER HABITAT FOR ARCTIC GRAYLING

DRAFT ALTERNATIVE 2 - TRIBUTARY DIVERSION AND POINT OF INFLOW MODIFICATION

PROJECT NO. FWP #33815A
FILE NAME: ------
SHEET NO. A-2 (2)

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: W. PARKER
DRAWN BY: W. PARKER
SHEET CHK'D BY: K. FLYNN
CROSS CHK'D BY:
APPROVED BY:
DATE: APRIL 2019

CDM Smith
560 N Park Ave #300
Helena, MT, 59601
Tel: (406) 441-1400

1/2" = 1000'
500 0 1000

UPPER RED ROCK LAKE, MONTANA:

PRELIMINARY ENGINEERING AND FEASIBILITY ANALYSIS TO IMPROVE WINTER HABITAT FOR ARCTIC GRAYLING

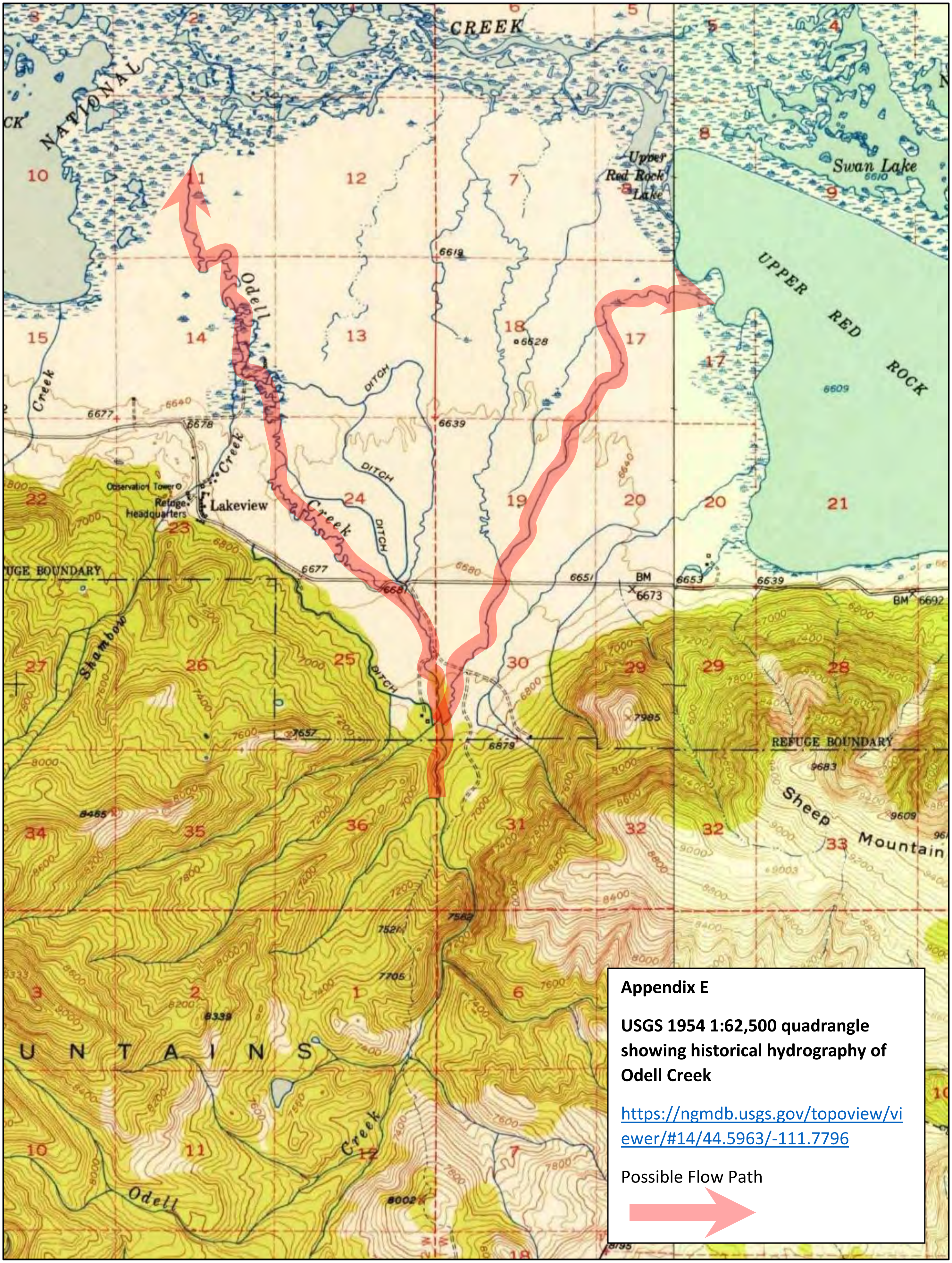
N

DRAFT ALTERNATIVE 3 - DREDGING AND VOLUME ENHANCEMENT

PROJECT NO. FWP #33815A
FILE NAME: ------
SHEET NO.
A-3

Appendix E

1954 Edition 1:62500 USGS Quadrangle



Appendix E

USGS 1954 1:62,500 quadrangle showing historical hydrography of Odell Creek

https://ngmdb.usgs.gov/topoview/viewer/#14/44.5963/-111.7796

Possible Flow Path