United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Colorado State Office
2850 Youngfield Street
Lakewood, Colorado 80215-7210

In Reply Refer To:
7250 (CO-932)

Mr. Rob Viehl
Colorado Water Conservation Board
1313 Sherman Street, Room 721
Denver, Colorado 80203

Dear Mr. Viehl:

The Bureau of Land Management (BLM) is writing this letter to formally communicate its recommendation for a natural lake level water right on Hack Lake, located in Water Division 5.

Location and Land Status. Hack Lake is located close to the southeast boundary of the Flattops Wilderness Area, approximately 12 miles northeast of Dotsero in the headwaters of the Hack Creek watershed. The lake is located within the NE ¼ SE ¼, Section 3, T3S R87W, Sixth Prime Meridian. The lake surface is bounded on the west by UTM X 316760 and on the east by UTM X 316920; the lake is bounded on the south at UTM Y 4409950 and on the north at UTM Y 4410060. All are in UTM Zone 13. The entire lake is located on public lands managed by BLM.

Biological Summary. Hack Lake is a cold water, high-altitude lake with a surface area of 1.29 acres. The mean depth of the lake at full pool is 6.4 feet with a maximum depth of 12.2 feet. The lake is continuously fed by a series of perennial springs located on the north shore of the lake, which maintain water quality in a suitable range for salmonids. The lake is located within porous volcanic geology, which facilitates groundwater inflow to the lake and surface water outflow through the bed of the lake.

Hack Lake supports cutthroat trout that are stocked periodically by Colorado Parks and Wildlife (CPW). The lake does not currently support natural recruitment of cutthroat trout because of the lack of suitable spawning areas. However, BLM and CPW are considering minor modification of the lakebed to provide a suitable spawning area. Protection of water levels is a prerequisite for further investments in habitat improvements. A spot survey of the lake revealed populations of mayflies and caddisfly, which serve as a primary food source for the trout population.

Water quality is suitable for long-term maintenance of trout populations. BLM collected water quality data in September 2021 that documented a pH of 8.69, water temperature of 9.7° Celsius, salinity of 0.1 parts per thousand, and specific conductivity of 77.

Hack Lake supports a riparian community comprised of willows, red-osier dogwood, aspen, twinberry, and sedges. The water supply and riparian vegetation attract heavy usage of the site by terrestrial wildlife, including deer, elk, bear, and mountain lion.

Hydrologic Analysis. A bathymetric survey and spring discharge survey were completed to support this recommendation.

CPW completed a bathymetric survey on September 23, 2021. A report describing the methodology used and survey results is provided as an attachment to this recommendation. The survey determined that at full pool, the lake stores 8.92 acre-feet of water. The bathymetric survey contains a stage-discharge table that enables the user to estimate the current volume of water in storage based upon various lake elevations.

BLM conducted a discharge measurement of the largest spring orifices on the north shore of the lake in September 2021. Total discharge from the three orifices was 140.22 gallons per minute. BLM notes that the Hack Lake watershed was in extreme drought condition at the time the discharge measurement was taken, and spring discharge was lowest ever observed by BLM staff.

BLM recommends that any quantity of water stored in Hack Lake, up to the full pool elevation of 9875.0 feet and up to 8.92 acre-feet of storage, be protected with a natural lake level water right.

Water Availability. The surface water elevation of Hack Lake varies throughout the year because of changing inflow rates and evapotranspiration rates. The lake is typically at full pool during the snowmelt runoff season, and then surface water elevation gradually recedes during the summer and fall as inflow from the springs located on the north shore of the lake decreases and as evapotranspiration from the lake increases.

At the time of the bathymetric survey described above, the surface water elevation of the lake was 2.9 feet below full pool. This is the lowest water level ever observed by BLM staff at the lake, and the water level is likely a response to severe drought.

BLM is not aware of any surface water diversions or groundwater diversions that are presently affecting the natural lake level.

Relationship to Land Management Plans. Maintenance of a natural lake level at Hack Lake is important to BLM for multiple reasons.

Hack Lake is located along the Johnny Meyer Trail, a major recreation access route to the Flattops Wilderness. BLM maintains a trailhead and camping area to support the use of this trail and Hack Lake. The fishing, wildlife viewing, and scenic viewing opportunities at Hack Lake are one of the key factors driving visitation.

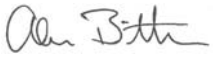
Maintenance of a natural lake level is also important for meeting BLM's wildlife habitat management objectives. BLM has committed to CPW that it will maintain this habitat for fishing opportunities and to provide a critical perennial water source for terrestrial

wildlife use. BLM also wishes to protect water availability for future wildlife habitat projects at the lake, which might include reclamation of the lake to introduce Colorado River Cutthroat Trout.

Information concerning the bathymetric survey, spring discharge, and fishery survey, as well as photographs, were included with BLM's draft recommendation in February 2022. BLM thanks both Colorado Parks and Wildlife and the Colorado Water Conservation Board for their cooperation in this effort.

If you have any questions regarding our instream flow recommendation, please contact Roy Smith at 303-239-3940.

Sincerely,



Alan Bittner
Deputy State Director, Resources

Cc: Larry Sandoval, Colorado River Valley Field Office
Colin Brady, Colorado River Valley Field Office
Greg Larson, Upper Colorado River District

Cutthroat Trout Studies

Kevin B. Rogers
Aquatic Research Scientist

2021 Progress Report

Colorado Parks & Wildlife

Aquatic Research Section

Fort Collins, Colorado

November 2021

STATE OF COLORADO

Jared Polis, Governor

COLORADO DEPARTMENT OF NATURAL RESOURCES

Dan Gibbs, Executive Director

COLORADO PARKS & WILDLIFE

Dan Prenzlow, Director

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Ex Officio/Non-Voting Members: Kate Greenberg, Dan Gibbs and Dan Prenzlow

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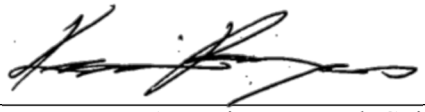
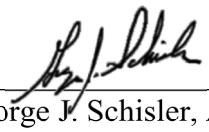
Tracy Davis, Hatchery Technician, Fish Research Hatchery
Andrew Perkins, Hatchery Technician, Fish Research Hatchery

Alexandria Austermann, Librarian

Prepared by: 

Kevin B. Rogers, Aquatic Research Scientist

Approved by: 

George J. Schisler, Aquatic Wildlife Research Chief

Date: 11/30/2021

The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Colorado Parks & Wildlife policy by the Director or the Wildlife Commission.

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RESEARCH PRIORITY

Cutthroat Trout habitat conservation

OBJECTIVE

Characterize the bathymetry and water volume in Hack Lake, Colorado

INTRODUCTION

The potential for commercial development of water in the headwaters of the Hack Creek watershed could jeopardize Hack Lake and the springs feeding it. To protect these waters for native trout and angling opportunity, the BLM intends to file for a natural lake level water right protection with the Colorado Water Conservation Board. Accurate bathymetric maps are needed in conjunction with spring source discharge (collected by BLM staff on the same day) for petitions to protect natural lake levels to be successful. Although Hack Lake currently does not support natural recruitment of Cutthroat Trout, robust spring inflows could allow for it if a suitable spawning channel were built. That combined with a reclamation project informed by the bathymetry developed here would provide for a wild naturally reproducing population. To facilitate potential future efforts, I maintained imperial units in all calculations.

METHODS

All mapping gear was packed 3.5 miles into Hack Lake, Garfield County, Colorado from the Hack Lake trailhead on September 22, 2021. Gear included a Humminbird model 597ci HD (Humminbird, Eufaula, Alabama) depth finder with a transducer deployed off the bow of an 8.5 lb pontoon boat (Figure 1; Model ODC 420 ULT, Creek Company, Steamboat Springs, Colorado) to acquire position and depth measurements every several seconds while using fins to propel the boat around the lake at about 0.8 kmph. This unit draws 550 mA, and was powered with a lightweight 12v lithium iron phosphate 9.6 AH battery (K2 Energy Solutions, Inc, Henderson, Nevada) that provided adequate power for the three-hour survey. The transducer face was set 10 in below the water surface, so all depth readings were increased by that amount. Two perimeters were was established by walking the Humminbird unit (without the transducer attached) around the shoreline with the sonar feature disabled (Setup Menu tab → Sonar → Off) and depth values defaulting to 0 ft. The first perimeter traced the existing waters edge at time of survey while the second approximated the full pool elevation, clearly visible during the time of the survey by changes in vegetation ringing the lake (Figure 1). BLM staff used standard survey procedures reveal that the lake elevation during the time of the survey was 2.9 feet lower than full pool levels on which the water rights should be filed. As such, this too was added to recorded depths, so that bathymetry and volumetric measurements reflect full pool conditions.

Figure 1. Hack Lake bathymetry was surveyed on September 22, 2021 with a surface elevation 2.9 ft below full pool elevation estimated by shoreline vegetation.

All transect data was then exported to SD flash media then imported to HumminbirdPC software so that transect locations could be visualized in GoogleEarth to aid in culling erroneous data. Individual transects were copied from HumminbirdPC using the “Select all” and “copy” commands then pasted into Excel where false depths (first record or shallow water) were eliminated. The Excel depth and perimeter files were then converted to ASCII tab delimited text for download into custom code written in LabVIEW software titled DecimalMinutesToDecimalDegrees.vi that converts decimal minutes recorded in the Humminbird unit to decimal degrees. Decimal degrees were converted to UTMs with the “Dutch formulae” (T. Neebling, Wyoming Game and Fish), then pasted into the depth and perimeter spreadsheets for each lake. Individual depth readings were converted to a raster map with 1 m grid cells using additional custom code (GenerateRasterHumminbird.vi) that calculates the average depth recorded in each cell. GPS error was listed as 0.6 m during the time of the survey. Transducer face depth was set 25 cm below the lake surface which was added back to each depth reading along with 2.9 ft to reflect the surface elevation drop from full pool conditions. Full pool perimeter coordinates were set to 0 ft depth while the actual surface perimeter was set to 2.9 ft. Corners of the map for Hack Lake were set at WestUTMx= 316760, EastUTMx= 316920, SouthUTMy= 4409950, and NorthUTMy= 4410060. Three files were created: a full pool perimeter file with depth = 0 feet, an actual perimeter file with depth = 2.9 ft, and a concatenated depth file with all remaining transects with depths rounded to the nearest foot increment (MapII GIS software can only handle integers). Output files were opened back up in Excel and converted to SYLK files (.slk) that were then opened in MapII (John Wiley & Sons, New York). All maps were inverted and rectified with the "Flip <map> vertically" operation. Command-I was used to get info on each layer and convert units to 1 m (adding the m is essential, as is selecting the m radio button).

A similar procedure was used to generate a map/mask of the lake perimeter coordinates. This

provided a point map defining the lake boundary that was made continuous manually in Map II (this is important to keep deep water readings from invading shore when interpolated) and the perimeter value was set to 0 in the legend (obtained while walking the shoreline). The depth layer was covered with the actual perimeter layer, and full pool perimeter layer, and the resulting map color reset to multichrome (Color → Color Sequence → Multichrome). The Cover command was used to join the perimeter file with the depth transects rather than Combine, as the latter will simply compress the legend to eliminate depths that have no values. Prior to interpolation, the map was smoothed using the Scan <map> Average function in MapII to reduce the influence of any erroneous GPS readings that might have remained undetected in the data. This new map was then interpolated by octants with a mask of the lake perimeter, weighting the nearest point within an octant by its distance from the target depth to be estimated. In order for the perimeter mask to function, it had to be filled in manually so that all points within the lake were non-void cells. I used the Page Setup function in MapII to adjust the size of the map, to include a scale and vertical legend (small), then exported to PICT Version2. This file was ungrouped in Superpaint (Aldus Corporation, Seattle, Washington) so that the position of the legend and scale could be changed, then regrouped and resaved as a PICT file. The PICT file was saved to a ZIP drive and imported into Microsoft Word as a picture. The map legend including raster counts for each depth strata was exported from MapII to an Excel file where surface area, mean and maximum depths, and volumetric measurements were calculated.

RESULTS & DISCUSSION

A total of 403 depth measurements were recorded while running 13 transacts on Hack Lake on September 22, 2021. Survey track placements are shown (Figure 2), but only represent 9 of the 13 tracks as 3.5 tracks had to be culled due to poor GPS coverage during approximately 45 min of the survey.

Figure 2. Nine depth tracks were run on Hack Lake and combined with a track of the wetted perimeter on September 22, 2021, projected in Google Earth.

The full pool perimeter mask revealed that the lake covers a surface area of 0.52 ha (1.29 acres). Because the lake elevation was down at the time of the survey, nearshore depths above the September 22nd 2021 elevation and full pool were inferred by interpolation. Lake mean depth at full pool is 1.96 m (6.4 ft), with a max depth of 3.72 m (12.2 ft). Volumetric estimates were generated from the interpolated map (Figure 3), displaying both metric and imperial units to facilitate reclamation effort planning. At full pool, Hack Lake is estimated to hold 11,005 m^3 (8.92 AF) of water. A formula that describes lake volume as a function of surface elevation was developed (Figure 4) to allow rapid estimation of lake volume at any elevation.

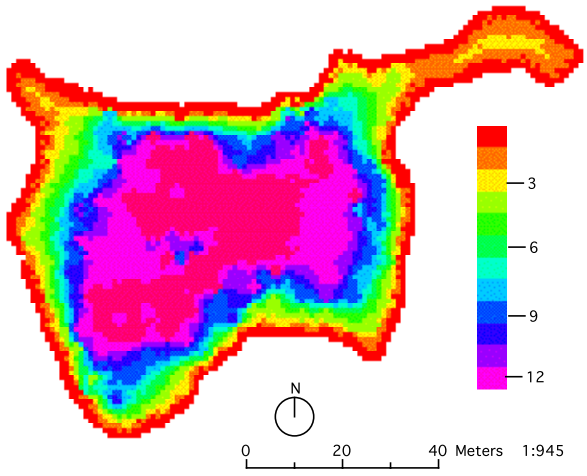


Figure 3. Nine depth transects obtained on Hack Lake were combined into a single file which was then covered by files containing all perimeter points at full pool and at time of survey, then interpolated by octants with a mask of the lake perimeter. The resulting bathymetric profile shows the average depth for each 1 m raster.

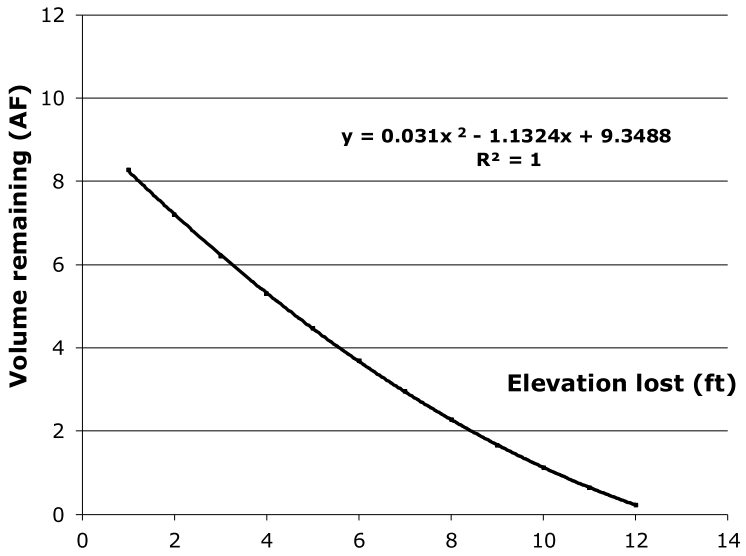


Figure 4. Total acre feet (AF) for every foot drop in lake elevation from our survey surface elevation was calculated, and fit with the second order polynomial shown. Results are expressed in imperial units to facilitate reclamation effort planning.

ACKNOWLEDGMENTS

I wish to acknowledge my collaborators Tom Fresques and Roy Smith from the BLM, and CPW Area Biologist Kendall Bakich.

Hack Lake Notes 9-23-21

- lake varies with snowmelt & spring inflow changes
- volcanic rock rings lake - review geo maps
- discharge through bottom of lake & evap
- eastern arm of lake dry
- riparian = dogwood, sedges, willows, aspen, twinberry
- located along Johnny Meyer trail
- heavy terrestrial wildlife use - deer, elk, ~~bear~~ bear, mountain lion
- heavy rec use - pack horses, multiple fire rings
- one spring developed w/ 2" PVC to enable filling containers
- no grazing - confirm with Tom
- fishery = cutthroat trout stocked aerially by CPW - may winter kill in some years
- mayflies, caddisfly

Spring #1 (largest) 316845 4410052

tape	depth	velocity	area	
1.30	0.00	0.00	[illegible]	
1.50	0.15	0.01	.045	.0005
1.70	0.10	0.12	.020	.0024
1.90	0.10	0.39	.020	.0078
2.10	0.20	0.23	.04	.0092
2.30	0.20	0.53	.04	.0212
2.50	0.20	1.40	.04	.0560
2.70	0.10	1.39	.020	.0278
2.90	0.10	1.26	.02	.0252
3.10	0.10	1.67	.02	.0334
3.30	0.10	1.63	.02	.0326
3.50	0.05	1.23	.01	.0123
3.70	0.05	0.77	.01	.0077
3.90	0.10	0.06	.02	.0012
4.10	0.05	0.00	.01	0
4.30	0.05	0.14	.01	.0014
4.50	0.05	[illegible]	0.98 .01	.0098
4.80	0.00	0.00	0	0

0.2485 cfs

Spring #2 (medium size) 316857 24100495

tape	depth	velocity	area	
0.70	0.0	0.0		
1.00	0.05	0.62	.02	.0124
1.20	0.05	0.92	.01	.0092
1.40	0.05	0.74	.01	.0074
1.60	0.05	0.61	.01	.0061
1.80	0.05	0.46	.01	.0046
2.00	0.05	0.32	.01	.0032
2.20	0.05	0.32	.01	.0032
2.40	0.05	0.41	.01	.0041
2.60	0.05	0.43	.01	.0043
2.80	0.05	0.33	.01	.0033
3.00	0.05	0.38	.01	.0038
3.10	0	0		

.0616 cfs

Spring #3 316853 4410050

1.32 gpm volumetric = .0029 cfs

Spring #1
pH = 8.70
Temp = 3.9° C
Salinity = 0
Cond. = 0

Total Discharge
#1 = .2485 cfs
#2 = .0616 cfs
#3 = .0029 cfs
.313 cfs
or
140.22 gpm

Lake Readings

pH = 8.69
Temp = 9.7° C
Salinity = 0.1 ppt.
Cond = 77

Water level in lake is 2.9 feet below high water line.

CPW Fish Sampling Report

Water Name: Hack & Horse Lakes **Water Code:** 67149 & 67389

Date Sampled: September 22 & 23

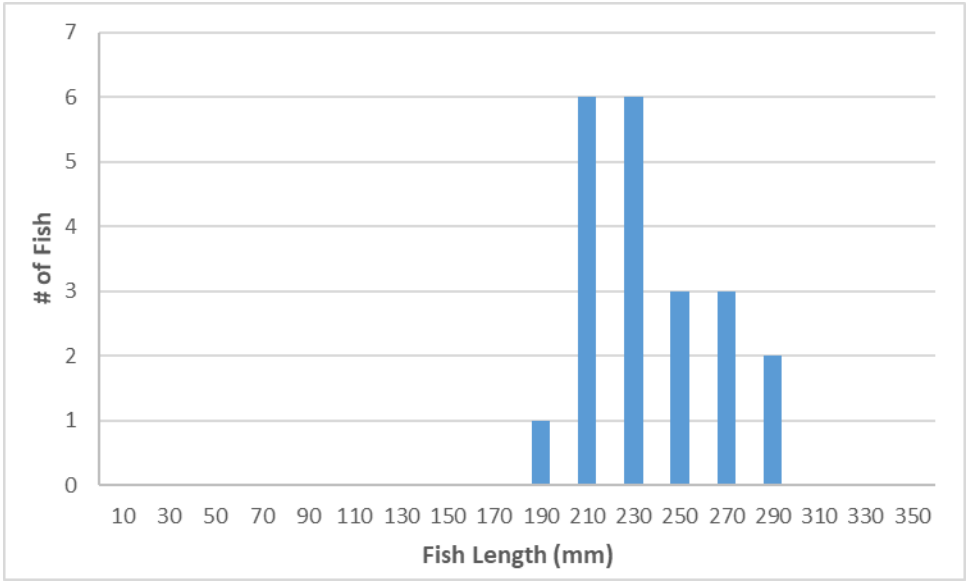
Purpose: Evaluate existing fishery using 75' experimental gillnets and anglers. Survey was conducted in concert with BLM evaluation of spring inputs to both lakes to support water rights filings. Bathymetric survey was also conducted on Hack Lake.

Results:

Hack Lake. Hack Lake is a thriving recreational cutthroat trout fishery. Cutthroat are visually abundant throughout the lake. Twenty-one (21) cutthroat trout were collected in two gillnets (total effort: 3.22 hours) and by Hook & Line (total effort: 1.97 hours) during the survey. Average size was 237mm and average Relative Weight (Wr) was 84.7. The following table summarizes fishery metrics documented during the September 22, 2021 survey:

	Gillnet	Hook & Line
CPUE (fish/hour)	4.3 fish/hour	4.0 fish/hour
Mean Length (mm)	244 mm	228 mm
Relative Weight (Wr)	83.8	87.1

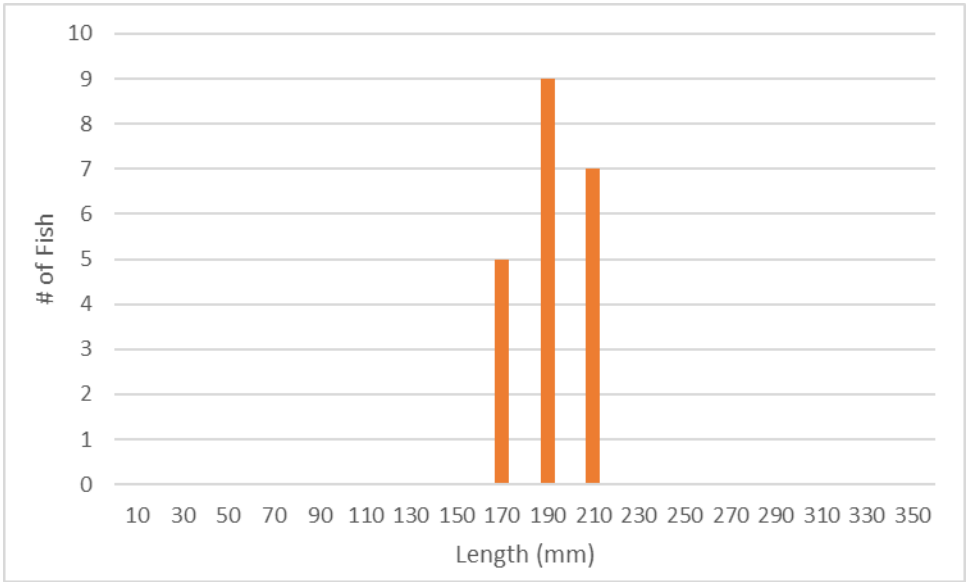
Length Frequency distribution of cutthroat trout:



Horse Lake. Horse Lake is a thriving wild brook trout trout fishery. Brook trout of all age classes are noticeably abundant throughout the lake. The lake has dense woody debris throughout from downed trees. Gillnet and Hook & Line methods were utilized to collect brook trout. Only one gillnet set was feasible due to the amount of woody debris. Twenty-one (21) brook trout were captured during the survey. The following table summarizes fishery metrics documented:

	Gillnet	Hook & Line
CPUE (fish/hour)	6 fish/hour	15 fish/hour
Mean Length (mm)	205 mm	189 mm
Relative Weight (Wr)	87	NA

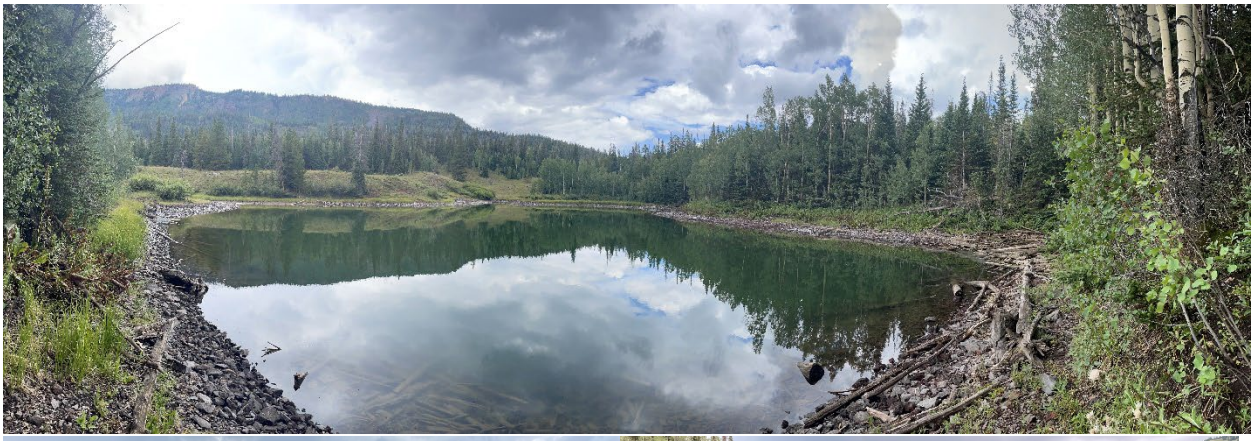
Length Frequency distribution of brook trout (though not captured, juvenile brook trout were observed by field personnel during the site visit):

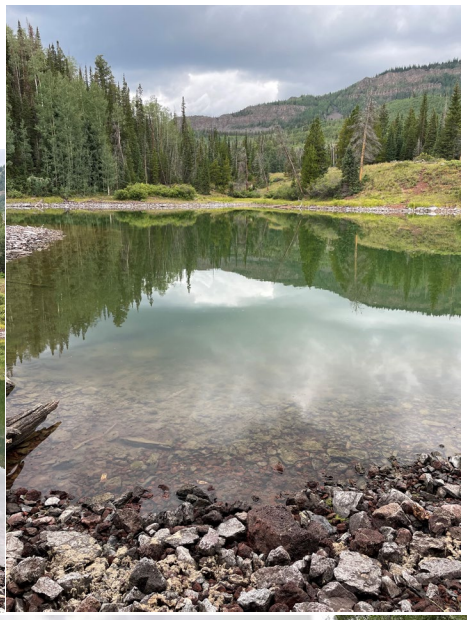


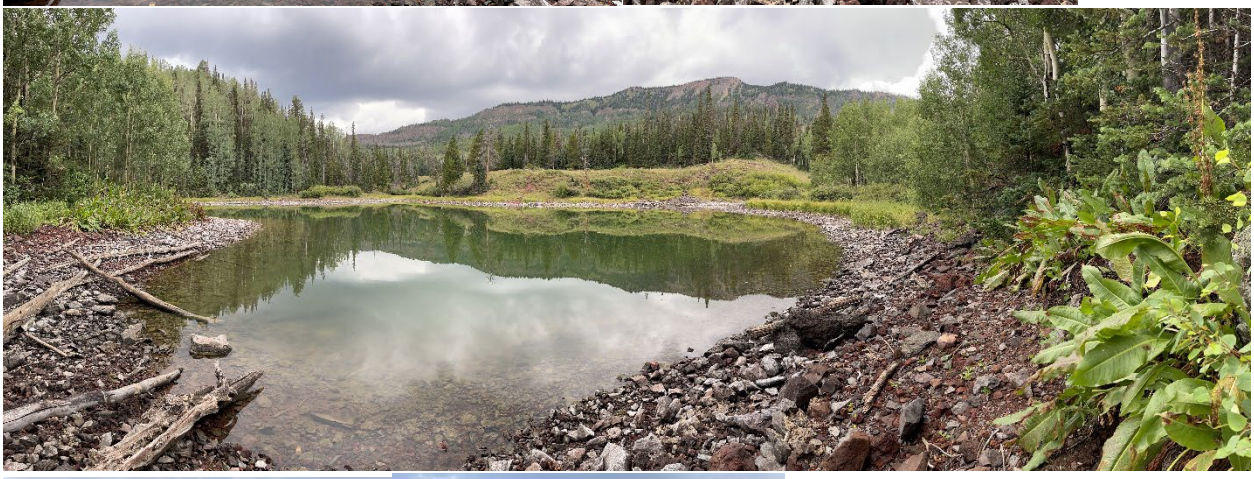
Management Implications:

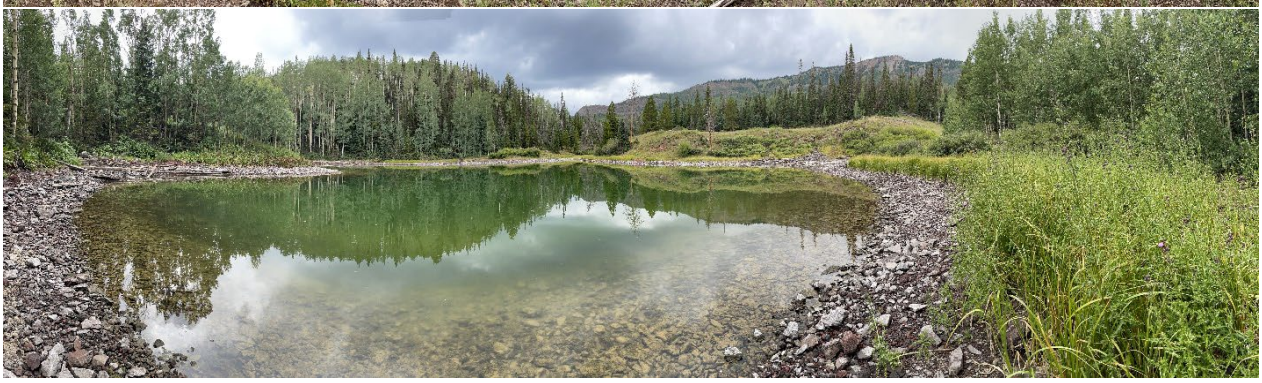
Hack Lake. The cutthroat fishery is sustained through regular airplane stocking. The outflow of the lakes goes subterranean and the inflowing spring stream length is short and relatively high gradient, thus resident cutthroat cannot utilize stream habitat for reproduction or habitation. Furthermore, inflows to the lake appear to be reduced with current drought conditions as the lake level was notably low. The fishery will sustain with continued stocking and as long as flows are enough to keep water quality conducive to fish survival. Particularly, inflows support dissolved oxygen in the winter and water depth that prevents excessive vegetation. Also, deeper water provides thermal refuges during the summer. If drought conditions persist or continue to reduce infows to the lake, winter kills of fish may be more frequent and stocking this lake may not be successful in maintaining the recreational fishery.

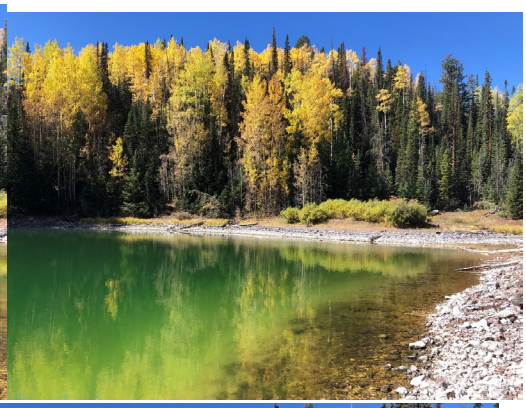
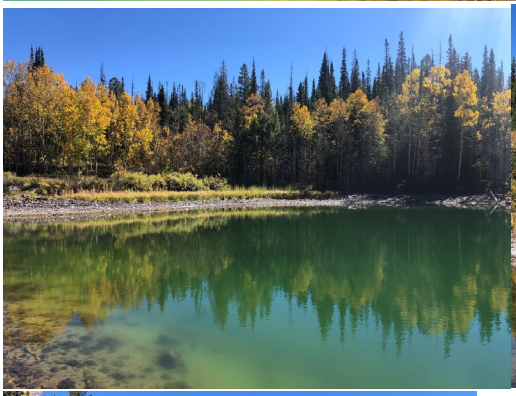
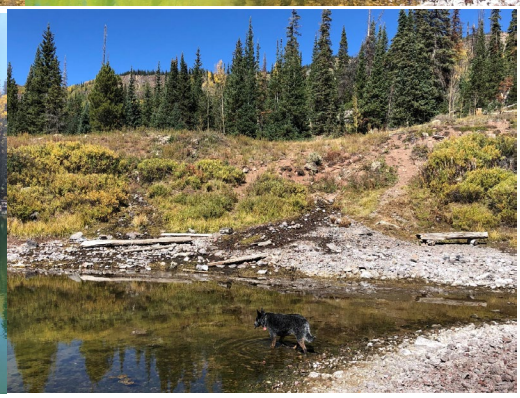
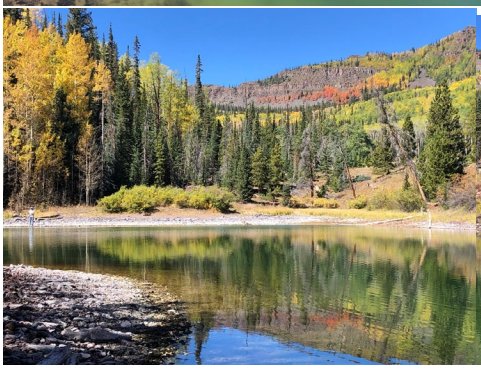
Horse Lake. The wild brook trout fishery is robust, if not over-populated, and can be sustained in its current condition. Lake level appeared to be maintained at historic levels with spring inflows despite drought conditions. This may indicate that either spring output has not significantly changed with drought or inflows from the springs is sufficient currently. As well, direct connection to the outlet stream allows trout to access a diversity of habitat (stream and lake) compared to Hack Lake.

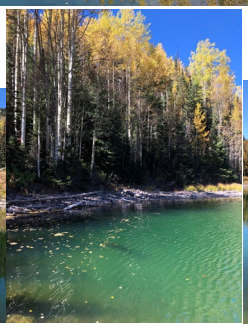










CREEK COMPANY
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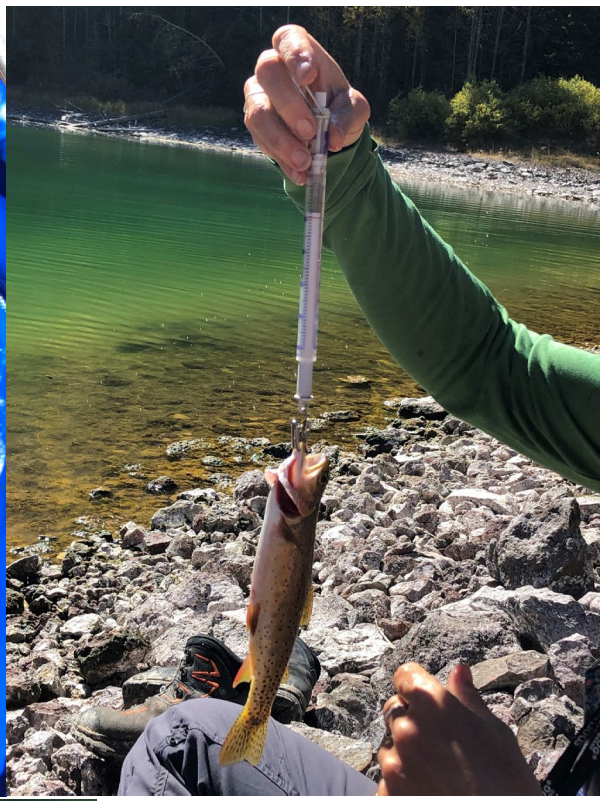
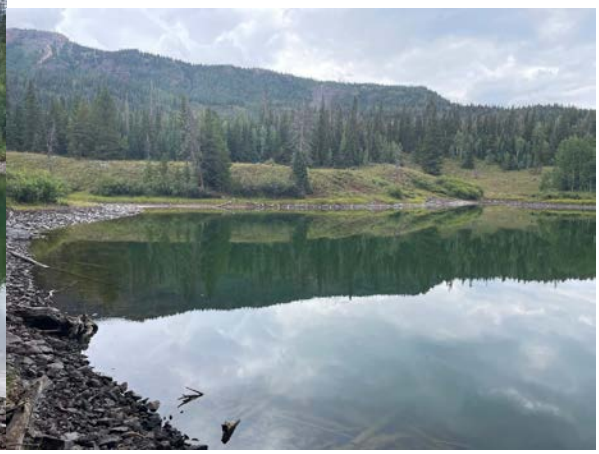
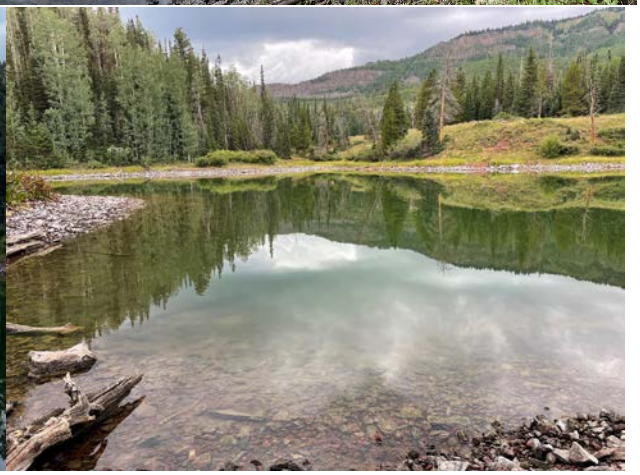


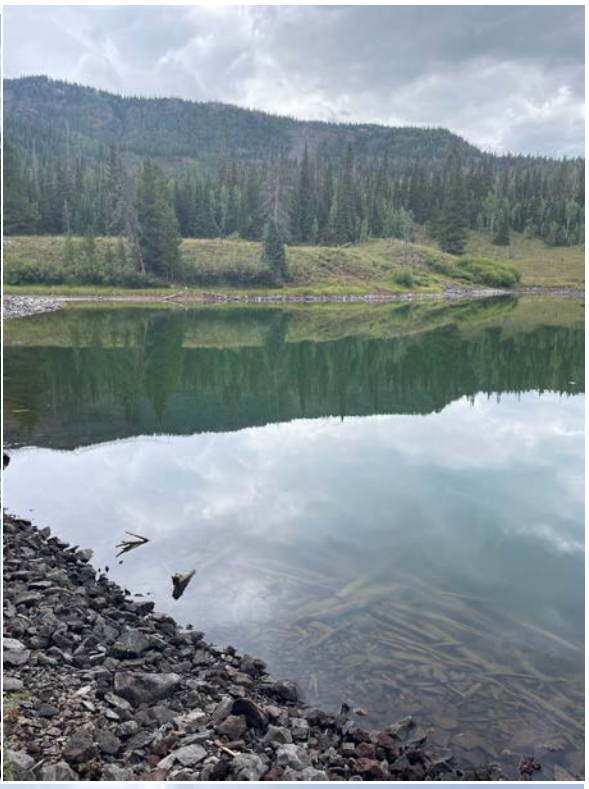
General Site Field Visit Data Report *(Filters: Name begins with Hack Lake;)*

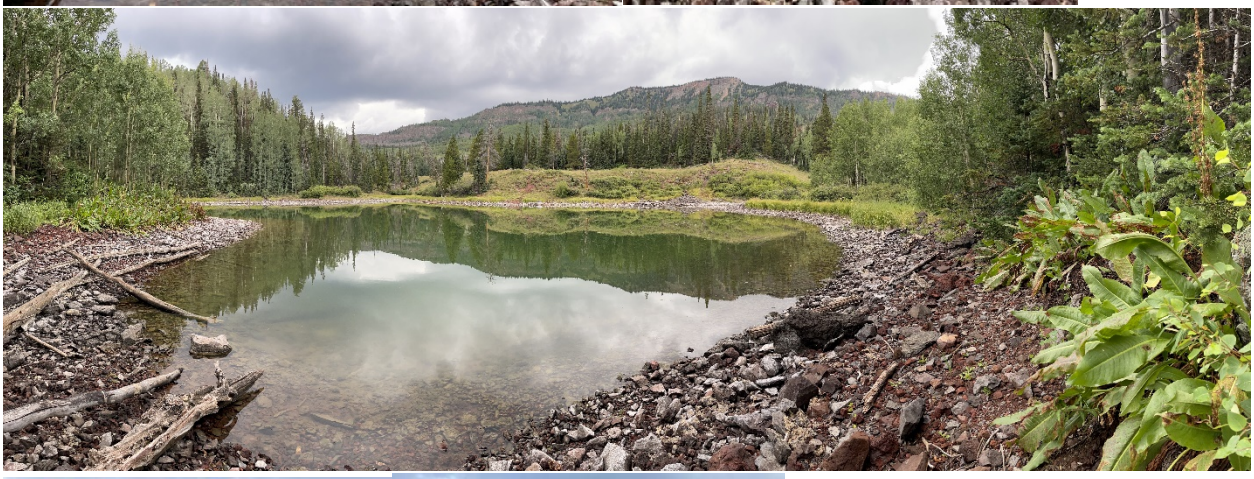
Type		Div	Name	UTM X	UTM Y	Segment ID	Visit Date	Location Description	Watershed Name
Lake		5	Hack Lake	316873	4410033	23/5/A-004	8/20/2022	Periphery of Hack Lake	Colorado Headwaters

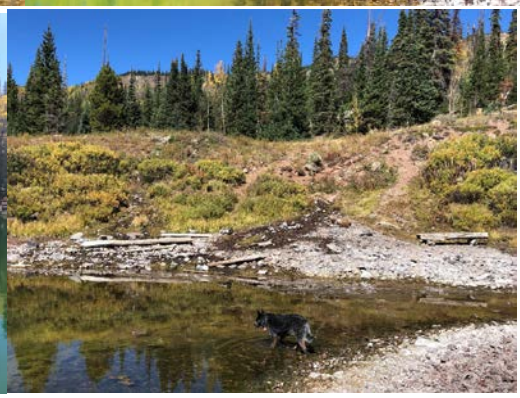
Remarks	Date	Remark
	20/08/22 13:00	Visual measurement of water level: 10 ft from top of ring formed by woody debri and plant growth.
	20/08/22 13:25	At least two of the springs inflowing at over 1cfs.

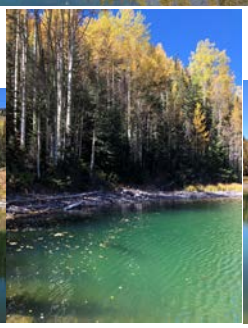


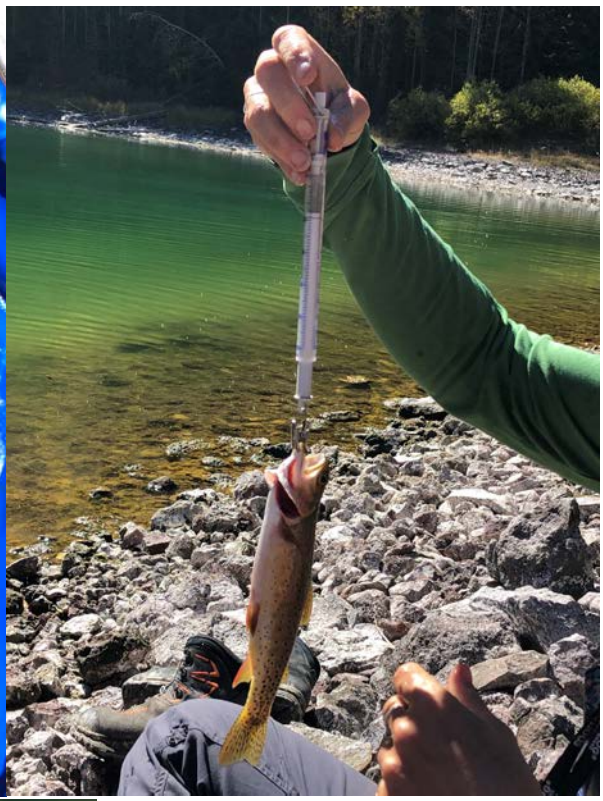












Cutthroat Trout Studies

Kevin B. Rogers
Aquatic Research Scientist

2021 Progress Report

Colorado Parks & Wildlife

Aquatic Research Section

Fort Collins, Colorado

November 2021

STATE OF COLORADO

Jared Polis, Governor

COLORADO DEPARTMENT OF NATURAL RESOURCES

Dan Gibbs, Executive Director

COLORADO PARKS & WILDLIFE

Dan Prenzlow, Director

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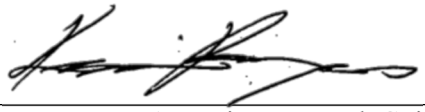
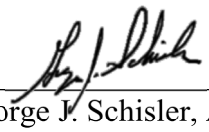
Alexandria Austermann, Librarian

Prepared by: 

Kevin B. Rogers, Aquatic Research Scientist

Approved by: 

George J. Schisler, Aquatic Wildlife Research Chief

Date: 11/30/2021

The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Colorado Parks & Wildlife policy by the Director or the Wildlife Commission.

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RESEARCH PRIORITY

Cutthroat Trout habitat conservation

OBJECTIVE

Characterize the bathymetry and water volume in Hack Lake, Colorado

INTRODUCTION

The potential for commercial development of water in the headwaters of the Hack Creek watershed could jeopardize Hack Lake and the springs feeding it. To protect these waters for native trout and angling opportunity, the BLM intends to file for a natural lake level water right protection with the Colorado Water Conservation Board. Accurate bathymetric maps are needed in conjunction with spring source discharge (collected by BLM staff on the same day) for petitions to protect natural lake levels to be successful. Although Hack Lake currently does not support natural recruitment of Cutthroat Trout, robust spring inflows could allow for it if a suitable spawning channel were built. That combined with a reclamation project informed by the bathymetry developed here would provide for a wild naturally reproducing population. To facilitate potential future efforts, I maintained imperial units in all calculations.

METHODS

All mapping gear was packed 3.5 miles into Hack Lake, Garfield County, Colorado from the Hack Lake trailhead on September 22, 2021. Gear included a Humminbird model 597ci HD (Humminbird, Eufaula, Alabama) depth finder with a transducer deployed off the bow of an 8.5 lb pontoon boat (Figure 1; Model ODC 420 ULT, Creek Company, Steamboat Springs, Colorado) to acquire position and depth measurements every several seconds while using fins to propel the boat around the lake at about 0.8 kmph. This unit draws 550 mA, and was powered with a lightweight 12v lithium iron phosphate 9.6 AH battery (K2 Energy Solutions, Inc, Henderson, Nevada) that provided adequate power for the three-hour survey. The transducer face was set 10 in below the water surface, so all depth readings were increased by that amount. Two perimeters were was established by walking the Humminbird unit (without the transducer attached) around the shoreline with the sonar feature disabled (Setup Menu tab → Sonar → Off) and depth values defaulting to 0 ft. The first perimeter traced the existing waters edge at time of survey while the second approximated the full pool elevation, clearly visible during the time of the survey by changes in vegetation ringing the lake (Figure 1). BLM staff used standard survey procedures reveal that the lake elevation during the time of the survey was 2.9 feet lower than full pool levels on which the water rights should be filed. As such, this too was added to recorded depths, so that bathymetry and volumetric measurements reflect full pool conditions.

Figure 1. Hack Lake bathymetry was surveyed on September 22, 2021 with a surface elevation 2.9 ft below full pool elevation estimated by shoreline vegetation.

All transect data was then exported to SD flash media then imported to HumminbirdPC software so that transect locations could be visualized in GoogleEarth to aid in culling erroneous data. Individual transects were copied from HumminbirdPC using the “Select all” and “copy” commands then pasted into Excel where false depths (first record or shallow water) were eliminated. The Excel depth and perimeter files were then converted to ASCII tab delimited text for download into custom code written in LabVIEW software titled DecimalMinutesToDecimalDegrees.vi that converts decimal minutes recorded in the Humminbird unit to decimal degrees. Decimal degrees were converted to UTMs with the “Dutch formulae” (T. Neebling, Wyoming Game and Fish), then pasted into the depth and perimeter spreadsheets for each lake. Individual depth readings were converted to a raster map with 1 m grid cells using additional custom code (GenerateRasterHumminbird.vi) that calculates the average depth recorded in each cell. GPS error was listed as 0.6 m during the time of the survey. Transducer face depth was set 25 cm below the lake surface which was added back to each depth reading along with 2.9 ft to reflect the surface elevation drop from full pool conditions. Full pool perimeter coordinates were set to 0 ft depth while the actual surface perimeter was set to 2.9 ft. Corners of the map for Hack Lake were set at WestUTMx= 316760, EastUTMx= 316920, SouthUTMy= 4409950, and NorthUTMy= 4410060. Three files were created: a full pool perimeter file with depth = 0 feet, an actual perimeter file with depth = 2.9 ft, and a concatenated depth file with all remaining transects with depths rounded to the nearest foot increment (MapII GIS software can only handle integers). Output files were opened back up in Excel and converted to SYLK files (.slk) that were then opened in MapII (John Wiley & Sons, New York). All maps were inverted and rectified with the "Flip <map> vertically" operation. Command-I was used to get info on each layer and convert units to 1 m (adding the m is essential, as is selecting the m radio button).

A similar procedure was used to generate a map/mask of the lake perimeter coordinates. This

provided a point map defining the lake boundary that was made continuous manually in Map II (this is important to keep deep water readings from invading shore when interpolated) and the perimeter value was set to 0 in the legend (obtained while walking the shoreline). The depth layer was covered with the actual perimeter layer, and full pool perimeter layer, and the resulting map color reset to multichrome (Color → Color Sequence → Multichrome). The Cover command was used to join the perimeter file with the depth transects rather than Combine, as the latter will simply compress the legend to eliminate depths that have no values. Prior to interpolation, the map was smoothed using the Scan <map> Average function in MapII to reduce the influence of any erroneous GPS readings that might have remained undetected in the data. This new map was then interpolated by octants with a mask of the lake perimeter, weighting the nearest point within an octant by its distance from the target depth to be estimated. In order for the perimeter mask to function, it had to be filled in manually so that all points within the lake were non-void cells. I used the Page Setup function in MapII to adjust the size of the map, to include a scale and vertical legend (small), then exported to PICT Version2. This file was ungrouped in Superpaint (Aldus Corporation, Seattle, Washington) so that the position of the legend and scale could be changed, then regrouped and resaved as a PICT file. The PICT file was saved to a ZIP drive and imported into Microsoft Word as a picture. The map legend including raster counts for each depth strata was exported from MapII to an Excel file where surface area, mean and maximum depths, and volumetric measurements were calculated.

RESULTS & DISCUSSION

A total of 403 depth measurements were recorded while running 13 transacts on Hack Lake on September 22, 2021. Survey track placements are shown (Figure 2), but only represent 9 of the 13 tracks as 3.5 tracks had to be culled due to poor GPS coverage during approximately 45 min of the survey.

Figure 2. Nine depth tracks were run on Hack Lake and combined with a track of the wetted perimeter on September 22, 2021, projected in Google Earth.

The full pool perimeter mask revealed that the lake covers a surface area of 0.52 ha (1.29 acres). Because the lake elevation was down at the time of the survey, nearshore depths above the September 22nd 2021 elevation and full pool were inferred by interpolation. Lake mean depth at full pool is 1.96 m (6.4 ft), with a max depth of 3.72 m (12.2 ft). Volumetric estimates were generated from the interpolated map (Figure 3), displaying both metric and imperial units to facilitate reclamation effort planning. At full pool, Hack Lake is estimated to hold 11,005 m^3 (8.92 AF) of water. A formula that describes lake volume as a function of surface elevation was developed (Figure 4) to allow rapid estimation of lake volume at any elevation.

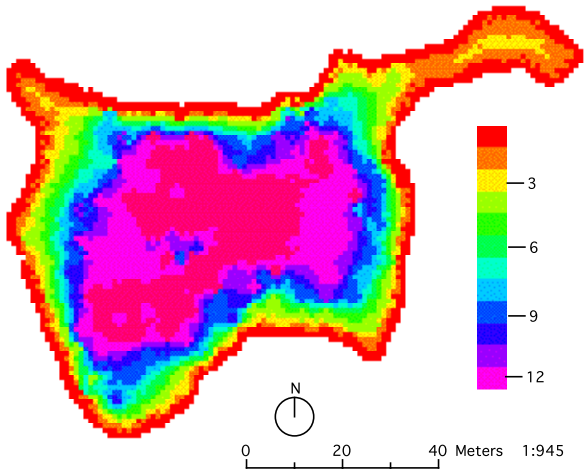


Figure 3. Nine depth transects obtained on Hack Lake were combined into a single file which was then covered by files containing all perimeter points at full pool and at time of survey, then interpolated by octants with a mask of the lake perimeter. The resulting bathymetric profile shows the average depth for each 1 m raster.

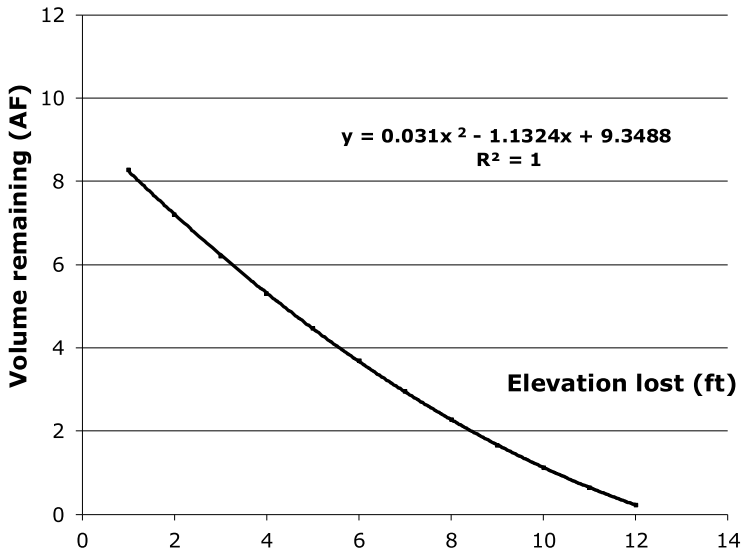


Figure 4. Total acre feet (AF) for every foot drop in lake elevation from our survey surface elevation was calculated, and fit with the second order polynomial shown. Results are expressed in imperial units to facilitate reclamation effort planning.

ACKNOWLEDGMENTS

I wish to acknowledge my collaborators Tom Fresques and Roy Smith from the BLM, and CPW Area Biologist Kendall Bakich.

Hack Lake Notes 9-23-21

- lake varies with snowmelt & spring inflow changes
- volcanic rock rings lake - review geo maps
- discharge through bottom of lake & evap
- eastern arm of lake dry
- riparian = dogwood, sedges, willows, aspen, twinberry
- located along Johnny Meyer trail
- heavy terrestrial wildlife use - deer, elk, ~~bear~~ bear, mountain lion
- heavy rec use - pack horses, multiple fire rings
- one spring developed w/ 2" PVC to enable filling containers
- no grazing - confirm with Tom
- fishery = cutthroat trout stocked aerially by CPW - may winter kill in some years
- mayflies, caddisfly

Spring #1 (largest) 316845 4410052

tape	depth	velocity	area	
1.30	0.00	0.00	[illegible]	
1.50	0.15	0.01	.045	.0005
1.70	0.10	0.12	.020	.0024
1.90	0.10	0.39	.020	.0078
2.10	0.20	0.23	.04	.0092
2.30	0.20	0.53	.04	.0212
2.50	0.20	1.40	.04	.0560
2.70	0.10	1.39	.020	.0278
2.90	0.10	1.26	.02	.0252
3.10	0.10	1.67	.02	.0334
3.30	0.10	1.63	.02	.0326
3.50	0.05	1.23	.01	.0123
3.70	0.05	0.77	.01	.0077
3.90	0.10	0.06	.02	.0012
4.10	0.05	0.00	.01	0
4.30	0.05	0.14	.01	.0014
4.50	0.05	[illegible]	0.98 .01	.0098
4.80	0.00	0.00	0	0

0.2485 cfs

Spring #2 (medium size) 316857 24100495

tape	depth	velocity	area	
0.70	0.0	0.0		
1.00	0.05	0.62	.02	.0124
1.20	0.05	0.92	.01	.0092
1.40	0.05	0.74	.01	.0074
1.60	0.05	0.61	.01	.0061
1.80	0.05	0.46	.01	.0046
2.00	0.05	0.32	.01	.0032
2.20	0.05	0.32	.01	.0032
2.40	0.05	0.41	.01	.0041
2.60	0.05	0.43	.01	.0043
2.80	0.05	0.33	.01	.0033
3.00	0.05	0.38	.01	.0038
3.10	0	0		

.0616 cfs

Spring #3 316853 4410050

1.32 gpm volumetric = .0029 cfs

Spring #1
pH = 8.70
Temp = 3.9° C
Salinity = 0
Cond. = 0

Total Discharge
#1 = .2485 cfs
#2 = .0616 cfs
#3 = .0029 cfs
.313 cfs
or
140.22 gpm

Lake Readings

pH = 8.69
Temp = 9.7° C
Salinity = 0.1 ppt.
Cond = 77

Water level in lake is 2.9 feet below high water line.

CPW Fish Sampling Report

Water Name: Hack & Horse Lakes **Water Code:** 67149 & 67389

Date Sampled: September 22 & 23

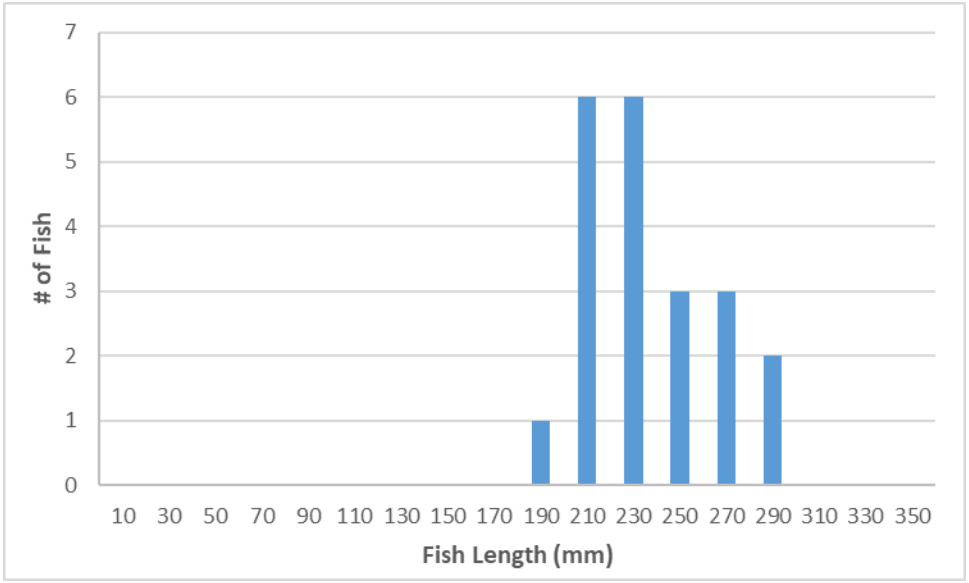
Purpose: Evaluate existing fishery using 75' experimental gillnets and anglers. Survey was conducted in concert with BLM evaluation of spring inputs to both lakes to support water rights filings. Bathymetric survey was also conducted on Hack Lake.

Results:

Hack Lake. Hack Lake is a thriving recreational cutthroat trout fishery. Cutthroat are visually abundant throughout the lake. Twenty-one (21) cutthroat trout were collected in two gillnets (total effort: 3.22 hours) and by Hook & Line (total effort: 1.97 hours) during the survey. Average size was 237mm and average Relative Weight (Wr) was 84.7. The following table summarizes fishery metrics documented during the September 22, 2021 survey:

	Gillnet	Hook & Line
CPUE (fish/hour)	4.3 fish/hour	4.0 fish/hour
Mean Length (mm)	244 mm	228 mm
Relative Weight (Wr)	83.8	87.1

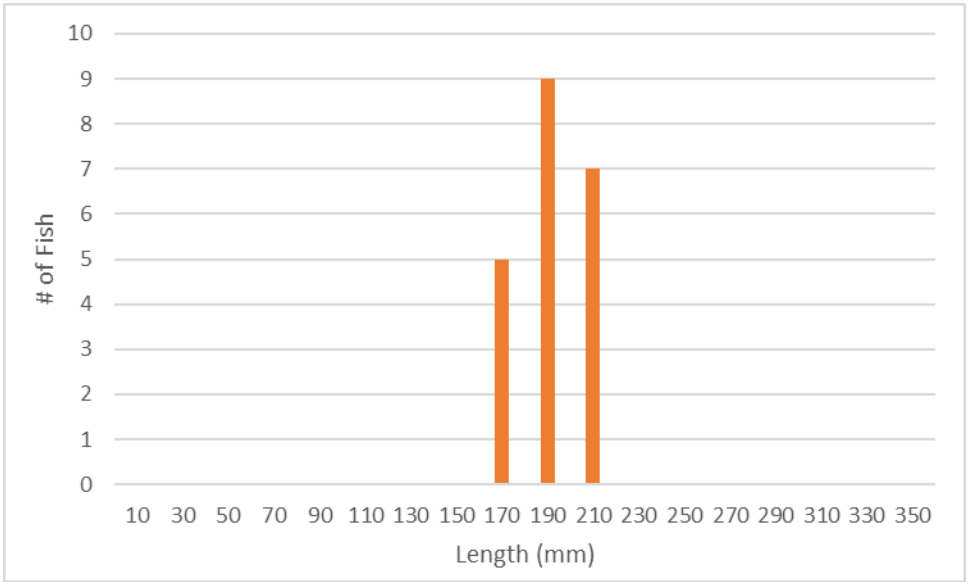
Length Frequency distribution of cutthroat trout:



Horse Lake. Horse Lake is a thriving wild brook trout trout fishery. Brook trout of all age classes are noticeably abundant throughout the lake. The lake has dense woody debris throughout from downed trees. Gillnet and Hook & Line methods were utilized to collect brook trout. Only one gillnet set was feasible due to the amount of woody debris. Twenty-one (21) brook trout were captured during the survey. The following table summarizes fishery metrics documented:

	Gillnet	Hook & Line
CPUE (fish/hour)	6 fish/hour	15 fish/hour
Mean Length (mm)	205 mm	189 mm
Relative Weight (Wr)	87	NA

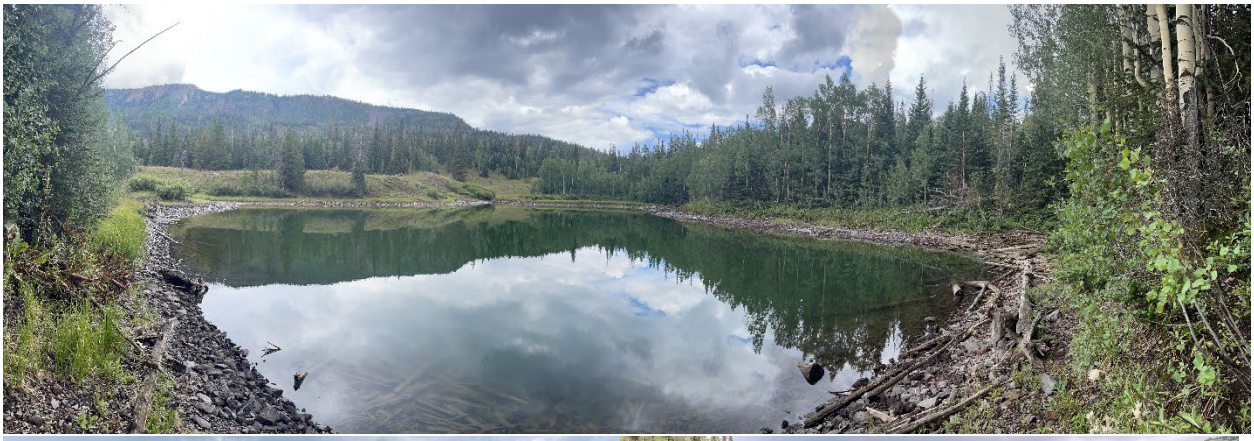
Length Frequency distribution of brook trout (though not captured, juvenile brook trout were observed by field personnel during the site visit):

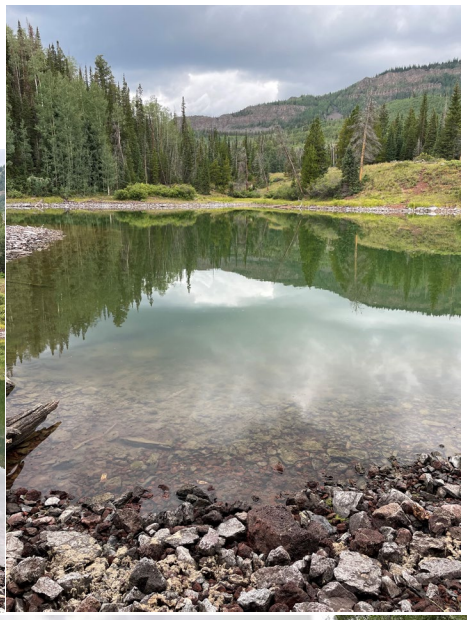


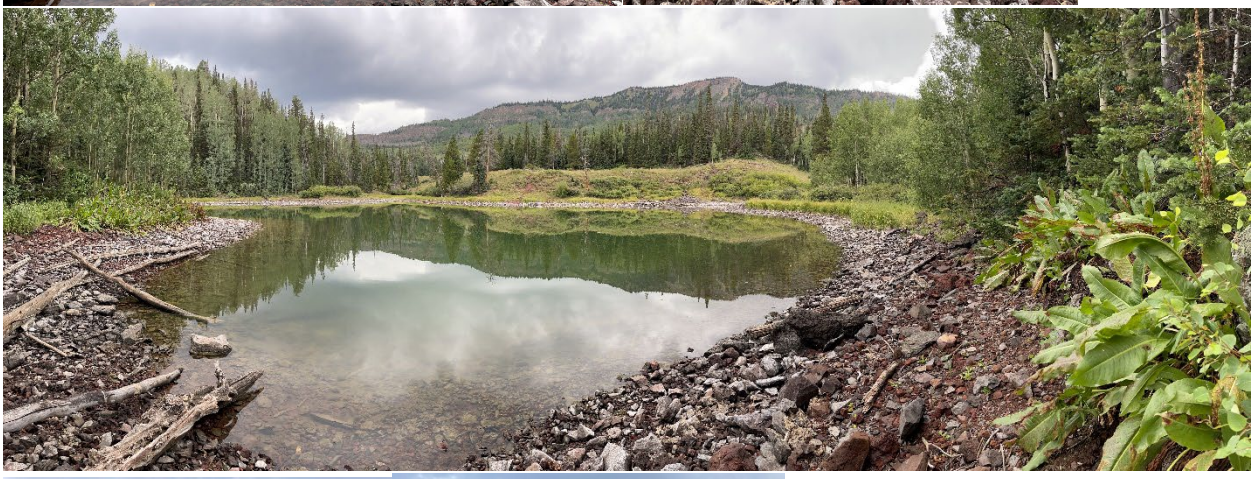
Management Implications:

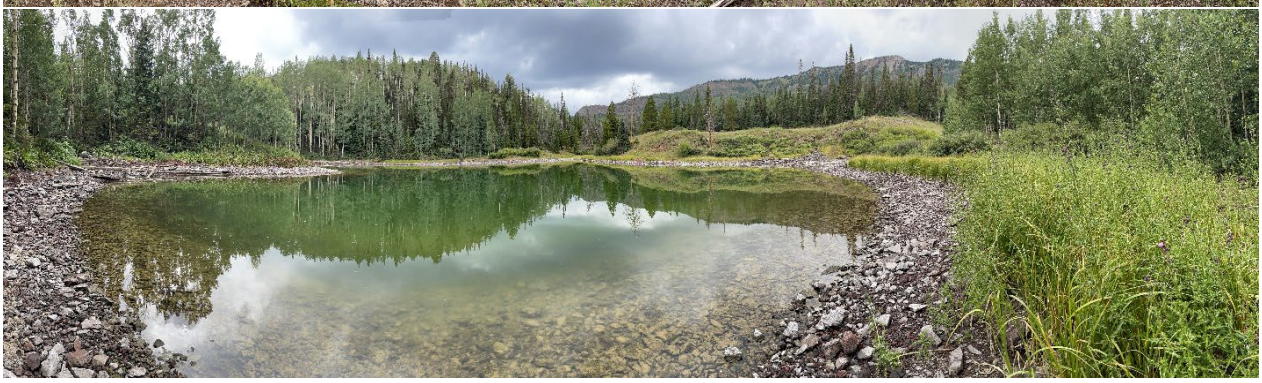
Hack Lake. The cutthroat fishery is sustained through regular airplane stocking. The outflow of the lakes goes subterranean and the inflowing spring stream length is short and relatively high gradient, thus resident cutthroat cannot utilize stream habitat for reproduction or habitation. Furthermore, inflows to the lake appear to be reduced with current drought conditions as the lake level was notably low. The fishery will sustain with continued stocking and as long as flows are enough to keep water quality conducive to fish survival. Particularly, inflows support dissolved oxygen in the winter and water depth that prevents excessive vegetation. Also, deeper water provides thermal refuges during the summer. If drought conditions persist or continue to reduce infows to the lake, winter kills of fish may be more frequent and stocking this lake may not be successful in maintaining the recreational fishery.

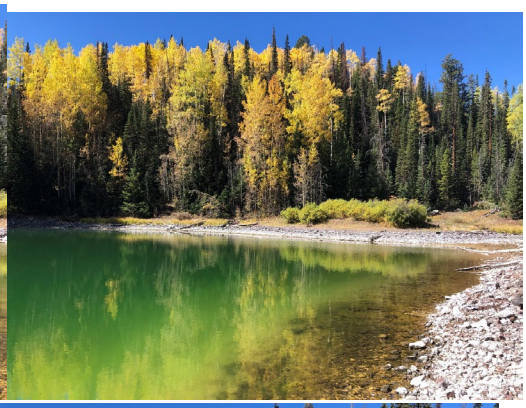
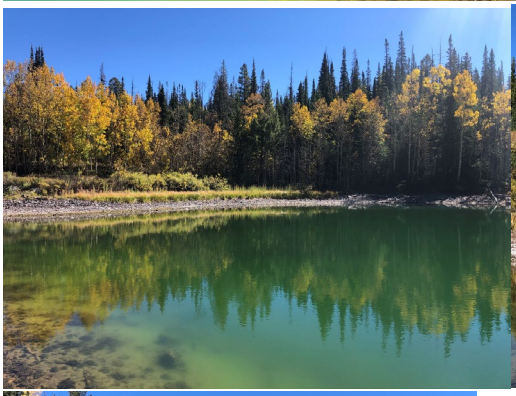
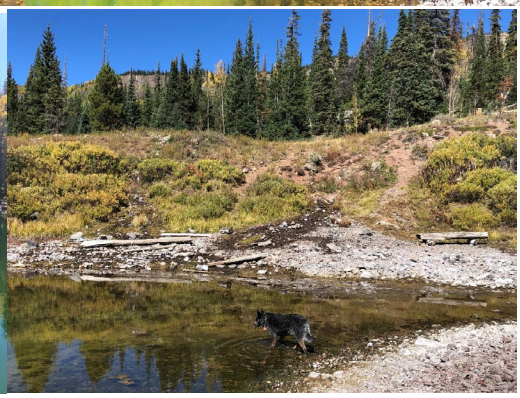
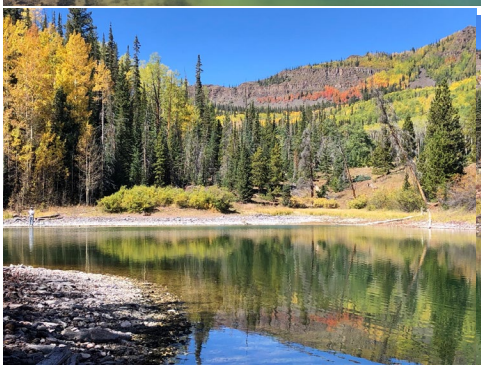
Horse Lake. The wild brook trout fishery is robust, if not over-populated, and can be sustained in its current condition. Lake level appeared to be maintained at historic levels with spring inflows despite drought conditions. This may indicate that either spring output has not significantly changed with drought or inflows from the springs is sufficient currently. As well, direct connection to the outlet stream allows trout to access a diversity of habitat (stream and lake) compared to Hack Lake.

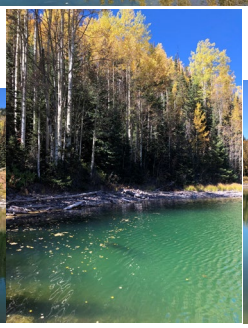




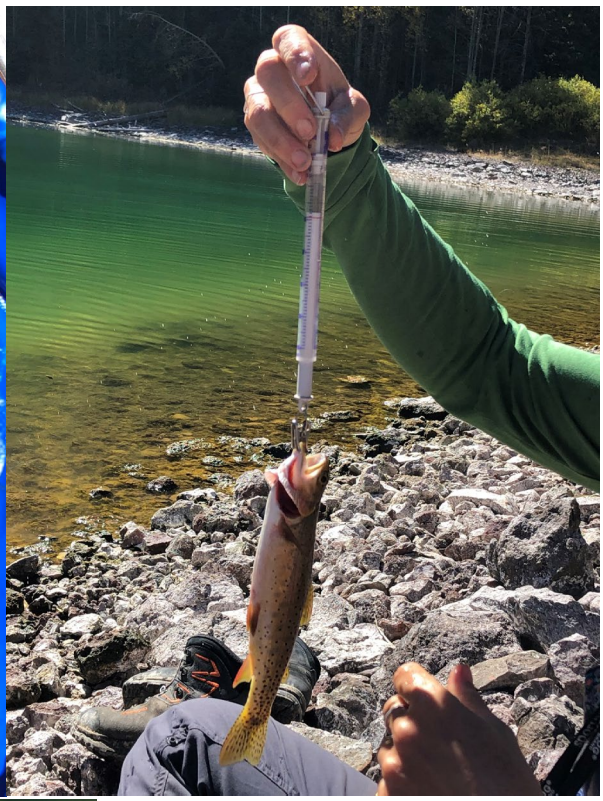






CREEK COMPANY
ODC 420 ULT



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