BONNEVILLE CUTTHROAT TROUT RESTORATION IN THE MAMMOTH CREEK DRAINAGE: 2020 ACTIVITIES

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Introduction

Native Bonneville cutthroat trout (BCT) were confirmed 98% pure in Mammoth Creek in 2012. The Mammoth Creek BCT Restoration Project was subsequently formulated with the goal of removing nonnative trout – primarily brook trout – from the Mammoth Creek drainage upstream of Mammoth Spring (Figure 1). Description of the drainage, history of fish management, details of the project, and progress through 2019 can be found in Hadley, et al. 2015, Hadley and Golden 2016a and b, Hadley and Golden 2019, and Hadley and Golden 2020.

Previous years' activities focused on nonnative trout removal in Mammoth Creek's tributaries. In 2020, the final phase of the project was commenced with nonnative removal in main stem Mammoth Creek, including the Meadow Lake system. The Reed Valley and John L Flat-Porcupine Lake-Dead Lake systems were also treated for a second time in 2020. Abundant private property in the Mammoth Creek headwaters required extensive contact and coordination with dozens of landowners.

Pathogen Surveys

Brook trout collected in John L Flat Creek and Porcupine Lake prior to rotenone treatment in 2019 were tested for infection by *Myxobolus cerebralis*, the parasite that causes whirling disease, at the Fisheries Experiment Station (FES) in Logan. (Such testing is regularly conducted prior to native trout restoration.) Results received in 2020 showed that the pathogen has not infected the John L Flat system. A sample of 30 brook trout was collected by electrofishing in Meadow Lake Creek, just upstream of Meadow Lake, in July 2020 and submitted for whirling disease testing. Results were not yet available as of January 2021. A 60-fish sample was also collected from Mammoth Creek near Mammoth Spring in October 2020 to maintain the certification for egg collection in 2021.

BCT Salvage

The infection of Mammoth Creek BCT with whirling disease has made replicating the population difficult. Utah's fish pathologist approved salvage and temporary holding of BCT during rotenone application in 2020. On August 3, crews collected 418 remnant BCT from the Mammoth Creek reach downstream of Castle Creek. The fish were held in a hatchery truck until rotenone concentration had sufficiently dissipated on August 7, then were returned to the stream in the same vicinity where they were collected.

Rotenone Treatments

Reconnaissance surveys were conducted throughout the target stream reaches during June and July 2020 to document brook trout distribution, as well as locations of springs, tributaries, seeps, and potential problem areas for rotenone application. Flow and water travel time were also measured in several locations. Due to extensive private property throughout the treatment area, property owners were contacted to coordinate application efforts. These contacts also assisted reconnaissance surveys in documenting water and fish extents.

John L Flat Creek, Porcupine Lake, Dead Lake

Rotenone was applied to target waters in John L Flat Creek upstream of Porcupine Lake on June 22, 2020, using three 4-hr (7-gal) drips. The top drip was set at a spring in John L Flat, with two boosters, 0.33 and 0.7 mi downstream (Fig. 2). Charges for drip stations were calculated to apply the liquid rotenone (5% active ingredient) at a concentration of 1.5 parts per

million (ppm). Spray crews were assigned to inspect the entire treatment area for potential refugia and areas of low mixing. Crews worked their way downstream and applied rotenone to these sites with backpack sprayers. Travel of rotenone through the treatment area was monitored by observation of sentinel fish set in live cages at each booster. Rotenone was applied to John L Flat Creek below Porcupine Lake on June 23, 2020. A 7-hr (35-gal) drip was set below the lake outlet (Fig. 3) and a spray crew walked the stream from this point to a series of cascades near the confluence with Mammoth Creek. Rotenone was also applied to Porcupine and Dead lakes on June 23 with backpack sprayers from both shore and a raft, as well as a water pump-aspirator system.

Table 1 lists personnel that participated in the treatments in the Mammoth Creek drainage in 2020, with assigned tasks. Drip 1 and the boosters were set in John L Flat Creek between 10:50 and 11:30 am on June 22, 2020 (Fig. 2). Rotenone traveled at rates similar to what was observed in 2019 (Table 2). Drips were pulled between 3:25 and 4:30 pm. One 10-inch brook trout was observed just downstream of Booster 1. Rotenone from the upper stream treatment was allowed to flow into Porcupine Lake after application. Drip 2 was set just below Porcupine Lake at 11:00 pm on June 22 and was pulled at 9:50 am on June 23. Application in Porcupine and Dead lakes was completed by noon on June 23. No fish were observed in the lakes or lower John L Flat Creek. A total of 1.26 gal (4.76 L) of rotenone was applied to John L Flat Creek on June 22 and 23 (Table 3) – 0.80 gal by drip stations and 0.46 gal by sprayers. 1.5 gal (5.68 L) were applied to Porcupine Lake and 5.0 gal (18.9 L) were applied to Dead Lake. Approximately 2.52 miles (4.06 km) of stream and 3.0 acres (1.22 ha) of lakes were treated with rotenone (Table 4). Experience from 2019 rotenone treatments showed no need for detox efforts in John L Flat or Reed Valley creeks (Hadley and Golden 2020). Catchable-sized tiger trout were stocked in Dead Lake one week following the treatment, in time for the July 4 holiday.

Reed Valley Creek

Liquid rotenone was applied to target waters in Reed Valley Creek on July 6 and 7, 2020, using three 35-gal (7-hr charge) drip barrels and one 7-gal (4-hr charge) drip barrel. The 35-gal barrels were set in the stream in upper Reed Valley (Drip 1) (Fig. 4), the main Reed Valley spring (Drip 2), and a spring (Drip 3) 0.65 mi downstream of the top drip. Drip 3 was close enough to the treatment midpoint that it was run as a booster. The 7-gal barrel (Drip 4) was set in another spring next to Drip 3. Spray crews were assigned to inspect the entire treatment area for potential refugia and areas of low mixing and applied rotenone to these sites with backpack sprayers.

Drips 1-3 were set in Reed Valley Creek at 11:00 pm on July 6 (Fig. 4). Although all of these drips were set for one 7-hr charge, Drips 1 and 2 emptied more slowly than anticipated and ran for about 10 hours before being pulled. Similar slow application rate also happened at these drips in 2019, though the resulting rotenone concentration still proved sufficiently lethal. Drip 3 was pulled after running just over 8 hours. Drip 4 was run for a single 2-hr charge on the morning of July 7. A total of 1.02 gal (3.87 L) of rotenone was applied to Reed Valley Creek on July 6 and 7 (Table 3) – 0.54 gal by drip stations and 0.48 gal by sprayers. Approximately 2.76 miles (4.44 km) of stream were treated with rotenone (Table 4). No fish were observed in the target area.

Meadow Lake and Tributaries

During reconnaissance surveys, it was found that the extreme upper headwater of

Meadow Lake Creek was isolated from the remainder of the stream by a reach of subsurface flow. In order to lessen the workload during the main treatment, rotenone was applied to this reach on July 29 and 30, 2020, using one 35-gal (7-hr charge) drip barrel, one 7-gal (4-hr charge) drip barrel, and one 32-oz bottle ("micro" drip). The 35-gal barrel was set upstream of the highest brook trout observed during reconnaissance (Fig. 5), while the 7-gal and micro drips were set in small tributaries. A spray crew was assigned to inspect the entire treatment area for potential refugia and areas of low mixing and applied rotenone to these sites with backpack sprayers. Drip 1 was set at 11:30 pm on July 29 (Fig. 5), recharged once at 6:30 am on July 30, then pulled at 10:00 am. Drip 2 was set at 7:00 am and run for 2.5 hours. Flow was greatly reduced during the treatment, with some seeps and tributaries drying up and brook trout congregating in only a few pools. Brook trout were found in low abundance throughout the treatment area. Several isolated pools that harbored fish in the dry reach during reconnaissance also dried up prior to the treatment, with only one pool remaining and supporting no fish. A total of 0.40 gal (1.51 L) of rotenone was applied to the Meadow Lake Headwater on July 29 and 30 (Table 3) – 0.24 gal by drip stations and 0.16 gal by sprayers.

The remainder of the Meadow Lake tributaries were treated on August 3 and 4. Three 35-gal (7-hr) drip barrels were set near the heads of three spring tributaries at 11:00 pm on August 3, while a fourth was set in another spring tributary at 4:00 am on August 4 (Fig. 6). (This tributary is ditched from its source through the Meadow Lake subdivision and was previously found to be fishless.) All four drips were set for a second charge, while Drips 1 and 2 were also set for a third. One micro drip was also set in the middle tributary. Flow was found to be moving much more slowly in the spring tributaries than was anticipated, though the third drip charges and repeated passes by spray crews accomplished full piscicide application by midday on August 4. Brook trout were abundant throughout the target area. A total of 1.99 gal (7.54 L) of rotenone was applied to Meadow Lake Creek and its tributaries above the lake (Table 3) – 1.01 gal by drip stations and 0.98 gal by sprayers. 2.71 mi (4.36 km) of Meadow Lake Creek were treated on July 29-30 and August 3-5 (the lowest reach was treated by outflow from the lake) (Table 4).

220 lbs (100 kg) of powdered rotenone (8.74% active ingredient) were applied to Meadow Lake on the morning of August 4 (Table 3). The pesticide was spread throughout the lake area using a boat-mounted aspirator system (title page photo). In addition, 1.50 gal (5.68 L) of liquid rotenone was applied to the shorelines and shallow areas with backpack sprayers. The lake was monitored throughout the day and numerous brook and brown trout were observed dying. By midafternoon, it appeared that the treatment had achieved a complete kill in Meadow Lake.

Harber Private Ponds

Brook trout were also observed in two small private ponds that feed a tributary to Mammoth Creek just north of Meadow Lake (Fig. 9). Liquid rotenone was applied to these two ponds on the morning of August 4 using a 7-gal drip barrel and backpack sprayers. A total of 0.34 gal (1.30 L) were applied to the ponds.

Mammoth Creek

Previous observation has noted that the reach of Mammoth Creek in between the two constructed barriers loses flow regularly in late summer (Fig. 1). Reconnaissance surveys in 2020 confirmed this, with the stream going from seven cubic feet per second (cfs) – its highest flow in the target area – at the upper barrier to completely dry less than 1.5 mi downstream. Flow

returned after approximately 0.25 mi, but was only two cfs at the campground (planned detox site). It was also found that the stream lost flow in the reach just downstream of FR 240 (Red Desert Road). At least three natural waterfalls were found below this point and upstream of the Castle Creek confluence. The waterfalls were located between 120347842E 4168547N and 120347929E 4168613N, and were all definite fish passage barriers (Fig. 12). Treatment personnel visited this area the day before rotenone application (August 4) and discovered that Mammoth Creek had also dried up for a short distance below the waterfalls. Treatment plans were adjusted to account for these two dry reaches. In addition, Lowder Creek and John L Flat Creek were found to be dry at their confluences with Mammoth Creek and did not require treatment.

Liquid rotenone was applied to target waters in Mammoth Creek on August 4 and 5, 2020, using twelve 35-gal (7-hr charge) drip barrels, thirteen 7-gal (4-hr charge) drip barrels, and eleven 32-oz (micro drip) bottles. The 35-gal barrels were set at major headwater points as well as locations along streams to act as boosters to the flow (Fig. 7-13). Most of these started applying rotenone at 10:00 to 11:00 pm on August 4 to facilitate overnight application and achieve coverage of the target area by morning. Some of the drips were set for a second charge on the morning of August 5. Seven-gal barrels were set on tributaries and in two remote booster locations (6 and 8) between 7:00 and 9:00 am on August 5 and were run for a single, 4-hr charge. Micro drips were set in small seeps and springs. Spray crews were assigned to inspect the entire treatment area for potential refugia and areas of low mixing and applied rotenone to these sites with backpack sprayers.

The 2020 monsoon rain season was almost nonexistent in southern Utah. Shortly after crews began to work on the rotenone application in Mammoth Creek on August 5, it became clear that stream flows had dropped even more since reconnaissance surveys and rotenone travel time had increased. On August 4, a number of beaver dams were pulled in the headwater reach to facilitate better flow in between beaver ponds. As spray crews worked through this reach, it became apparent that the opposite effect was achieved, with flow drying up between the ponds. The ponds were effectively treated by the spray crews, while micro drips were set heavier (4 oz rotenone as opposed to 1 oz) to help boost rotenone concentration between Drip 3 and Booster 1 (Fig. 7). Despite these complications, full coverage of the headwater reach was achieved by midday.

The Ireland Meadow crew (Fig. 8) saw few complications other than Drip 6 being initially set in an isolated, unconnected seep. The problem was quickly discovered and the drip set in the correct location. Brook trout were found just 15 feet below Drip 7 in the “Cheerio” pond tributary, so the drip was set for a second charge just upstream. This charge was later moved downstream to a small beaver pond at the road crossing to make sure that the lower reach of the tributary was treated thoroughly.

Booster 2 was found to be emptying very slowly, with only 10 of 35 gallons of mixture being dispensed in the seven hours overnight (Fig. 8). Rotenone had not yet reached FR 041 by 6:50 am, though it was expected to reach Booster 4 by that time (Fig. 9). The drip head was cleaned out but continued to run slow, so the barrel cap was later removed to speed up application. Another 35-gal drip barrel (Booster 2a) was set in Mammoth Creek at 7:00 am, at the end of Blue Bird Lane in the Rainbow Meadow subdivision. Crews observed dead fish at this point when the drip was set, but set it there anyway because there was no other good access point downstream. Extra rotenone was added to Drip 8 to help boost concentration, while the Booster

4 barrel was moved upstream to FR 041 (Booster 2b) after its first charge had ended. Rotenone flowing out of Meadow Lake reached Booster 4 by 6:00 am, so a second charge was not needed at that confluence. Low density of fish made it hard to note downstream flow of rotenone in the Harber ponds outflow, so a 7-gal drip (Booster 3a) was also set in the lower reach of this stream at 11:30 am to make sure that the entire reach was treated.

As in higher reaches, rotenone was observed to move more slowly through the reaches between Boosters 4 and 6 (Fig. 10, Table 2). Very few fish were observed between Booster 5 and the waterfalls. Spray crews moved slowly to stay behind the rotenone front and ensured that complete coverage was achieved. Reduced flow had already been noted in reaches below the waterfalls (Fig. 11-13) and adjusted application plans successfully addressed those reductions. The rotenone charge in Drip 14 (Castle Creek) was increased to treat the entire flow of Mammoth Creek, while Booster 6 was moved to below the waterfalls and changed to a 7-gal drip. The dry reach in the lower treatment section had grown to 0.29 mi on August 5.

A total of 10.9 gal (41.5 L) of rotenone was applied to Mammoth Creek and its tributaries on August 4 and 5 (Table 3) – 7.7 gal by drip stations and 3.3 gal by sprayers. Approximately 13.98 miles (22.52 km) of stream were treated with rotenone on those dates (Table 4). Brook trout were abundant through most of the treatment area, while brown trout were observed in limited abundance downstream of Meadow Lake. BCT were found below the waterfalls and in Castle Creek (though most were removed during salvage), while a handful of tiger trout were also observed in Castle Creek.

Potassium permanganate ($KMnO_4$) was applied to toxic waters at a constant rate using an auger-hopper system to deactivate the rotenone below the target area. The detox station was set at the Mammoth Creek campground, with a backup station set up at the Mammoth Spring confluence (Fig. 13). Sentinel fish (splake trout provided by Mammoth Creek hatchery) were placed both upstream (to monitor rotenone arrival) and downstream (to monitor deactivation) of the detox station. Sentinel fish were also set in the spring channel to monitor whether toxic rotenone concentration would travel subsurface from above the dry reach to the spring. Application of $KMnO_4$ began at 7:15 am on August 5. Rotenone reached detox from Booster 8 at 8:30 am. The backup detox was started at 9:15 am after one of the sentinel fish in the spring channel cage died. None of the other fish in the cage showed any signs of stress, however, indicating that the fish was likely already compromised when placed in the cage. The backup detox was shut off at 11:20 am. The main detox continued applying $KMnO_4$ until 10:30 am on August 6. Application rate averaged 28 g/min for the first thirteen hours but was reduced to 17 g/min after sentinel fish activity indicated that rotenone concentration was declining. Application continued at this rate for 14.5 hours. Overall, the oxidizer was applied at a mean rate of 22.1 g/min for 27.25 hours. Monitoring of sentinel fish below the detox station indicated that the rotenone was successfully deactivated below the target area. 91.3 lbs (41.5 kg) of $KMnO_4$ were applied at the two detox stations (Table 3).

Discussion

Repeat rotenone applications in the John L Flat and Reed Valley systems proceeded without complications in 2020, thanks to adjustments made after the 2019 treatments. Reduced flow and equipment malfunction presented challenges to the treatment of Mammoth Creek; however, experienced treatment personnel were well prepared to meet these challenges and still accomplish the goal of a complete eradication. (Conversely, increased flow may have

complicated treatment in headwater reaches of both Mammoth Creek and Meadow Lake by increasing freshwater refugia.) Although the large crew size (Table 1) required extensive coordination and supervision, it also allowed personnel to focus troubleshooting on their own target reach. These two factors – experienced personnel and adequate crew size – made all the difference in achieving what appeared to be a successful treatment. The simplest adjustment that can be made to address reduced flow and slow travel time during 2021 will be to move the treatment to mid-July. Main drips and boosters can also start running earlier than 11:00 pm, though this will require them to be checked and recharged earlier than 6:00 am. If flow is continuous throughout the target area, then detox should be expected to last longer than 24 hours. The project can be further simplified by splitting application up more than was done in 2020.

Cooperation with private landowners was also a key to the success of the Mammoth Creek project in 2020. The Martin and Harber families were particularly instrumental, as they own extensive land in the headwaters of Meadow Lake, as well as the Martins owning the lake itself. Frank Martin also donated $5,000 to UDWR in 2020 to support the Mammoth Creek treatment project. Meadow Lake will be treated as early as possible in summer 2021 so that the sport fishery can be reestablished quickly. (UDWR will provide tiger trout and BCT for stocking). The Martins plan to install pipes on the lake's outlet culverts to create a temporary barrier until the rest of the drainage can be treated in mid-July. The Harbers' main (upper) pond was isolated from the other ponds during summer 2020 (Fig. 9). Because this pond provides the family's angling throughout the summer, it was not included in the initial treatment. The Harbers also said that they had never seen brook trout in that pond. An attempt to sample the pond with fyke nets in fall 2020 failed to catch any fish and sampling with gill nets was delayed until the Harbers were done using the pond for the season. Other regional projects also delayed this sampling until mid-November, when it was discovered that the pond does support a limited number of brook trout, in addition to the sterile rainbow trout that the family purchases. Unfortunately, the pond froze over just one week later, preventing any attempt to treat the pond with rotenone in the fall. This pond will also be treated as soon as possible in summer 2021 and UDWR will provide tiger trout to replace the lost fish.

The salvage of BCT in Mammoth Creek will allow another attempt at collecting eggs in spring 2021. If successful, this spawn could provide fish for stocking throughout the drainage. Until a concerted effort at egg take can be fully evaluated (this may take two to three more years) it is recommended that only Mammoth Creek progeny or triploid Manning Meadow BCT be stocked in Mammoth Creek. If unsuccessful, the Mammoth Creek remnant will at least be preserved, though it will eventually mix with Manning Meadow BCT. Salvage efforts will again be necessary in 2021 to make this possible.

In total, 22 miles (35 km) of stream and 15 acres (6 ha) of lakes (Table 4) were treated with rotenone in the Mammoth Creek drainage during 2020, marking one of the larger removal projects attempted by UDWR in southern Utah in recent years. When the project is completed, the drainage will support up to 30 miles (48 km) of habitat for BCT.

Literature Cited

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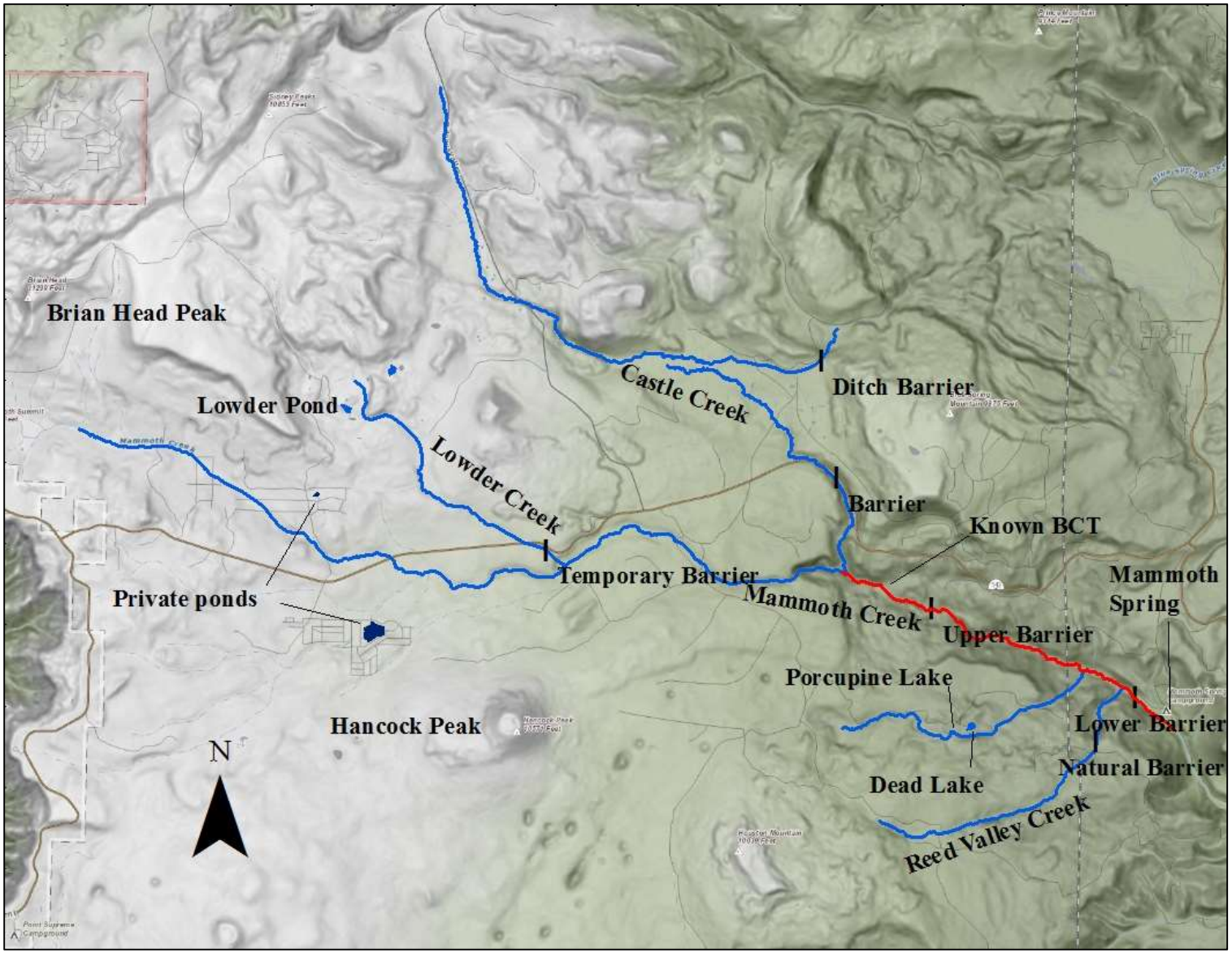

Figure 1. Upper Mammoth Creek drainage.

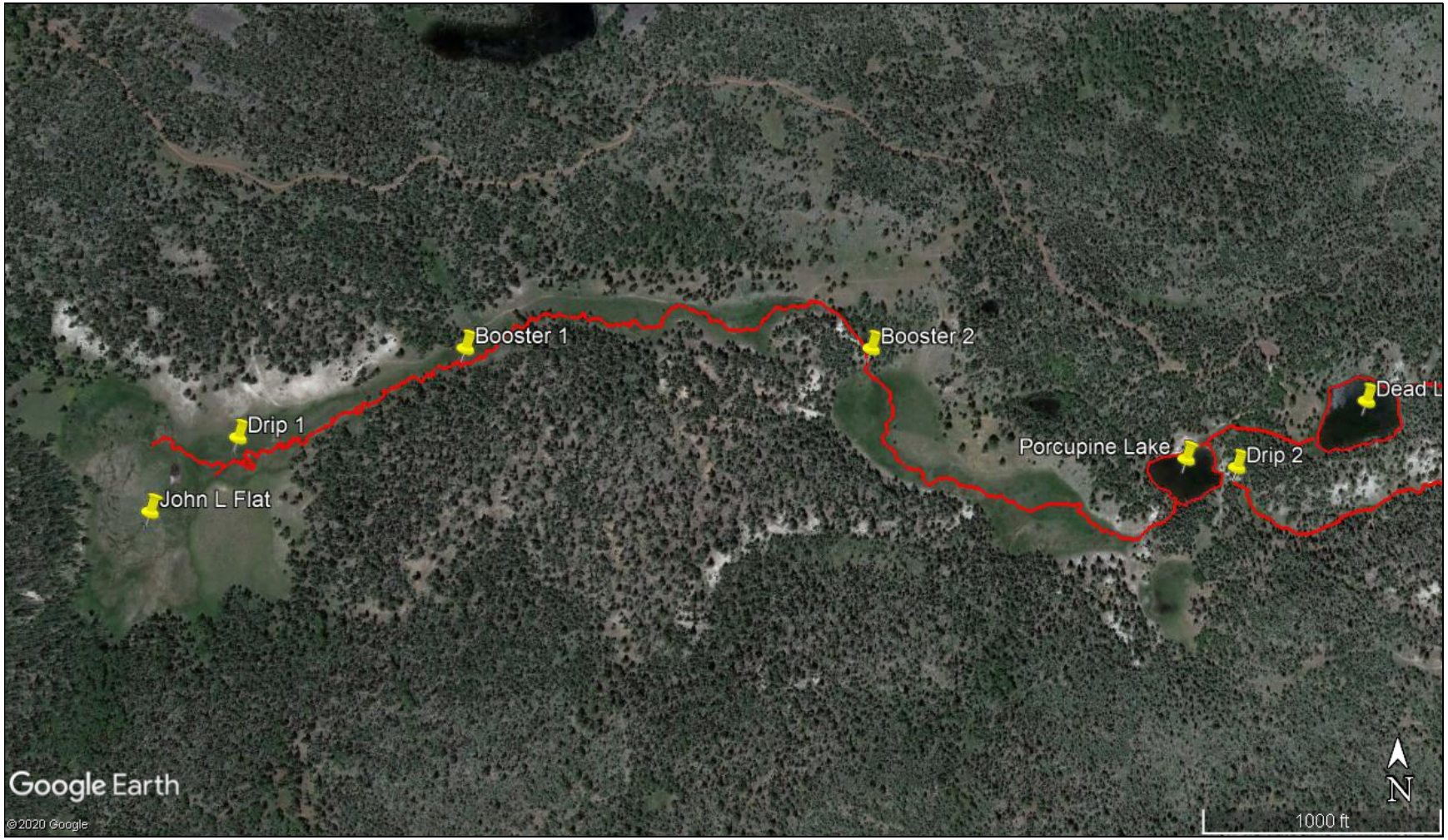

Figure 2. Locations of rotenone drip stations set between John L Flat and Porcupine Lake.

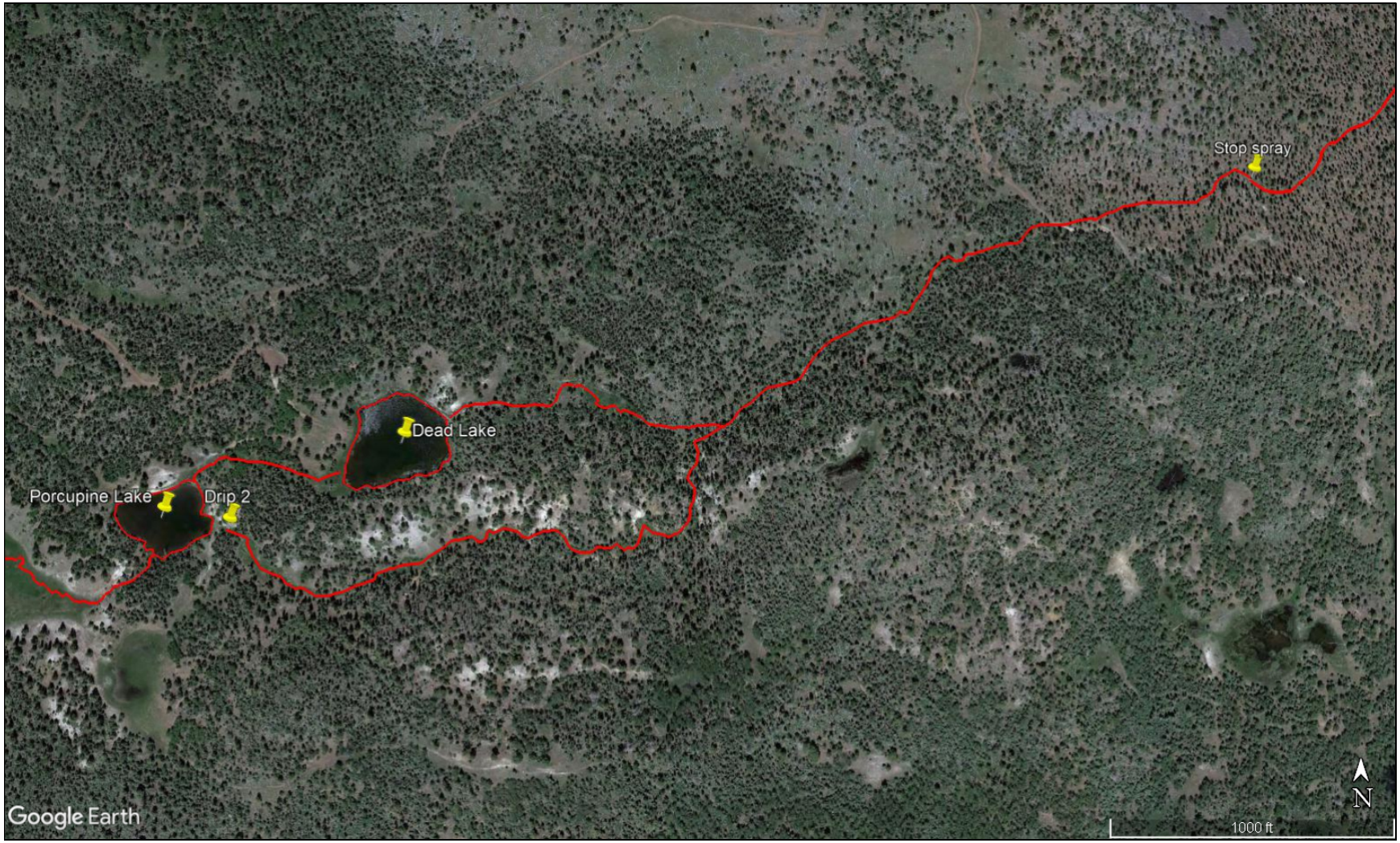

Figure 3. John L Flat Creek below Porcupine and Dead lakes.

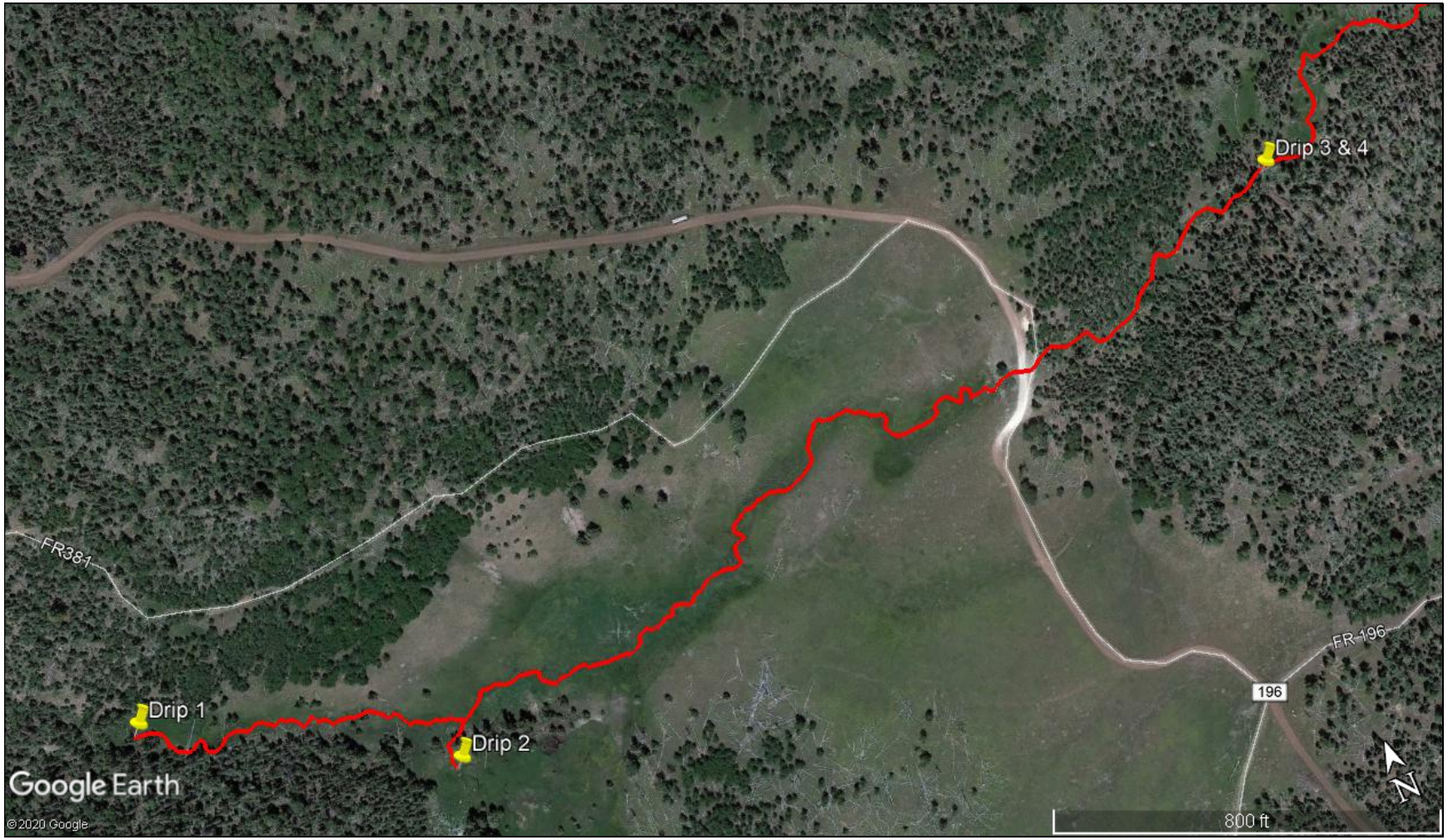

Figure 4. Locations of rotenone drip stations in upper Reed Valley Creek.

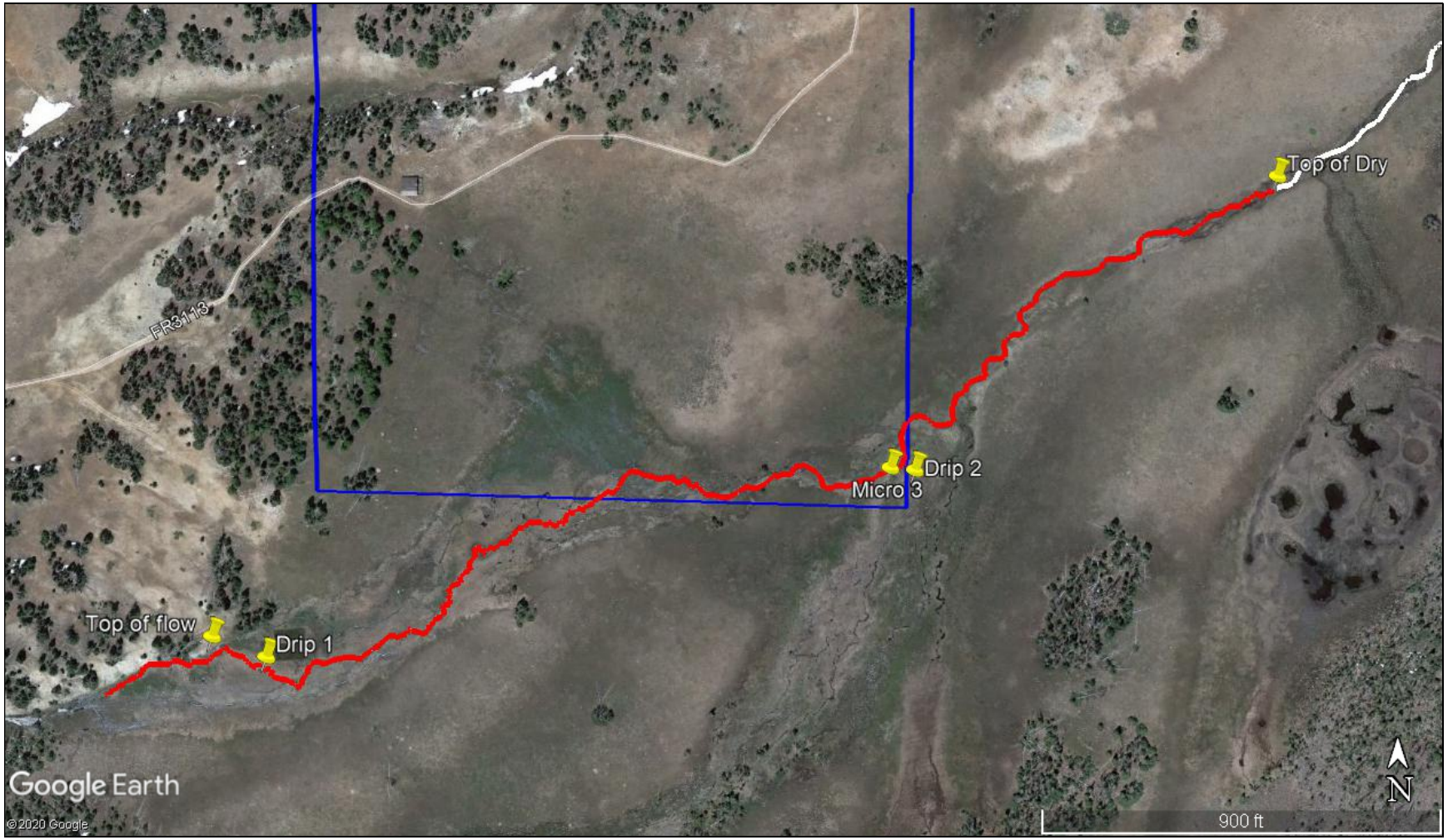

Figure 5. Locations of rotenone drip stations set in the isolated headwater of Meadow Lake Creek.

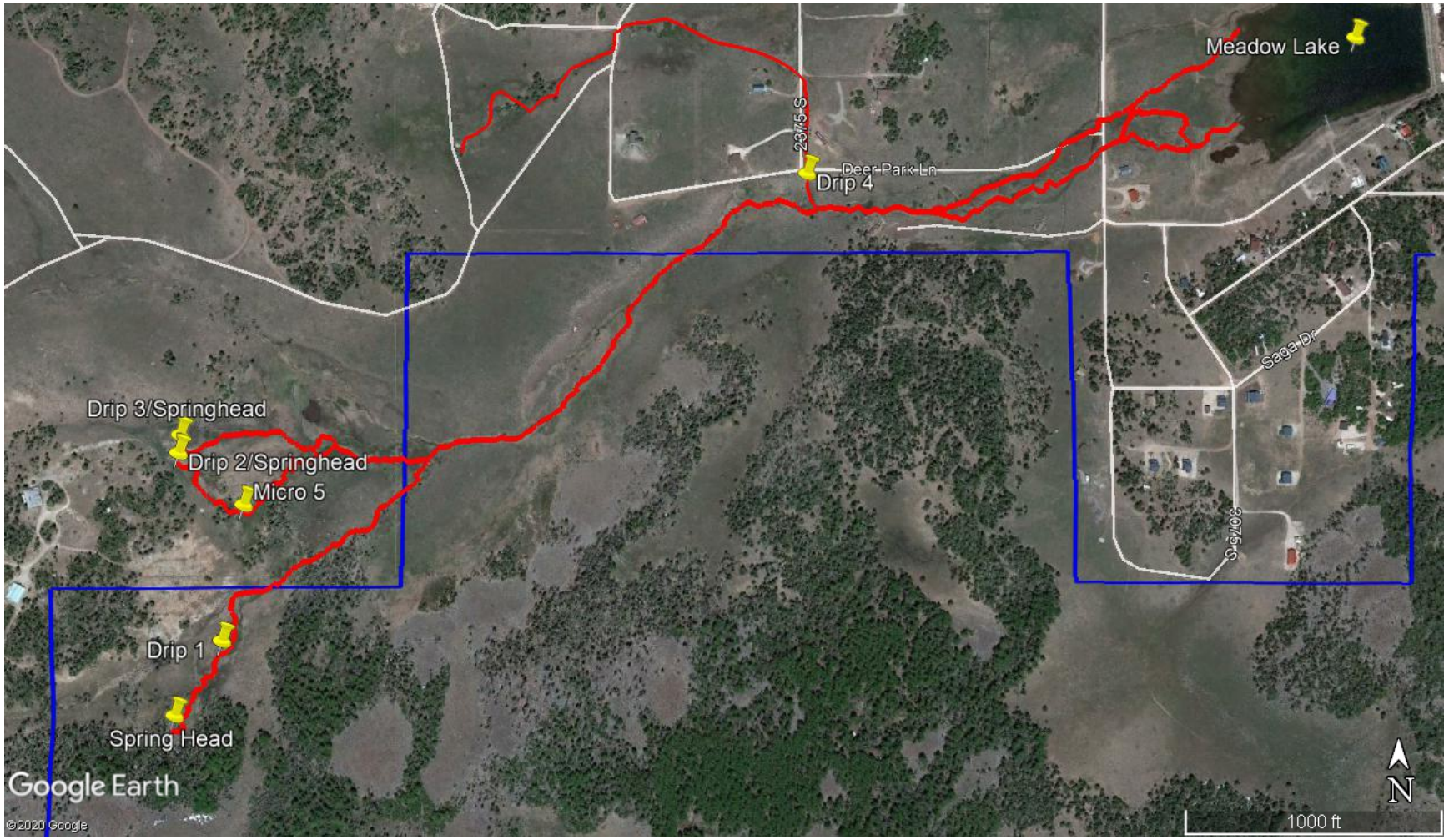

Figure 6. Locations of rotenone drip stations set in the headwaters of Meadow Lake.

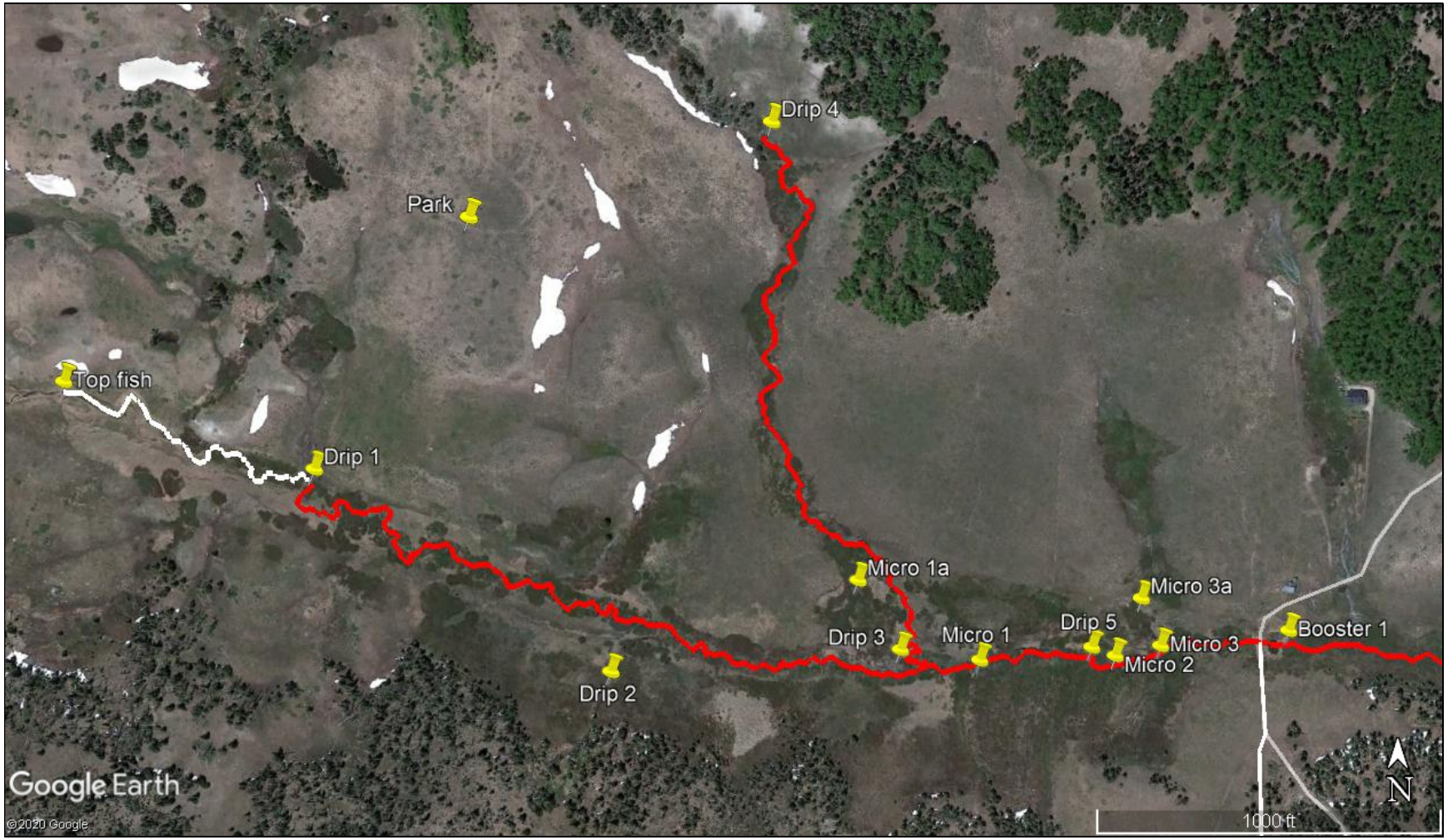

Figure 7. Locations of rotenone drip stations set in the headwaters of Mammoth Creek.

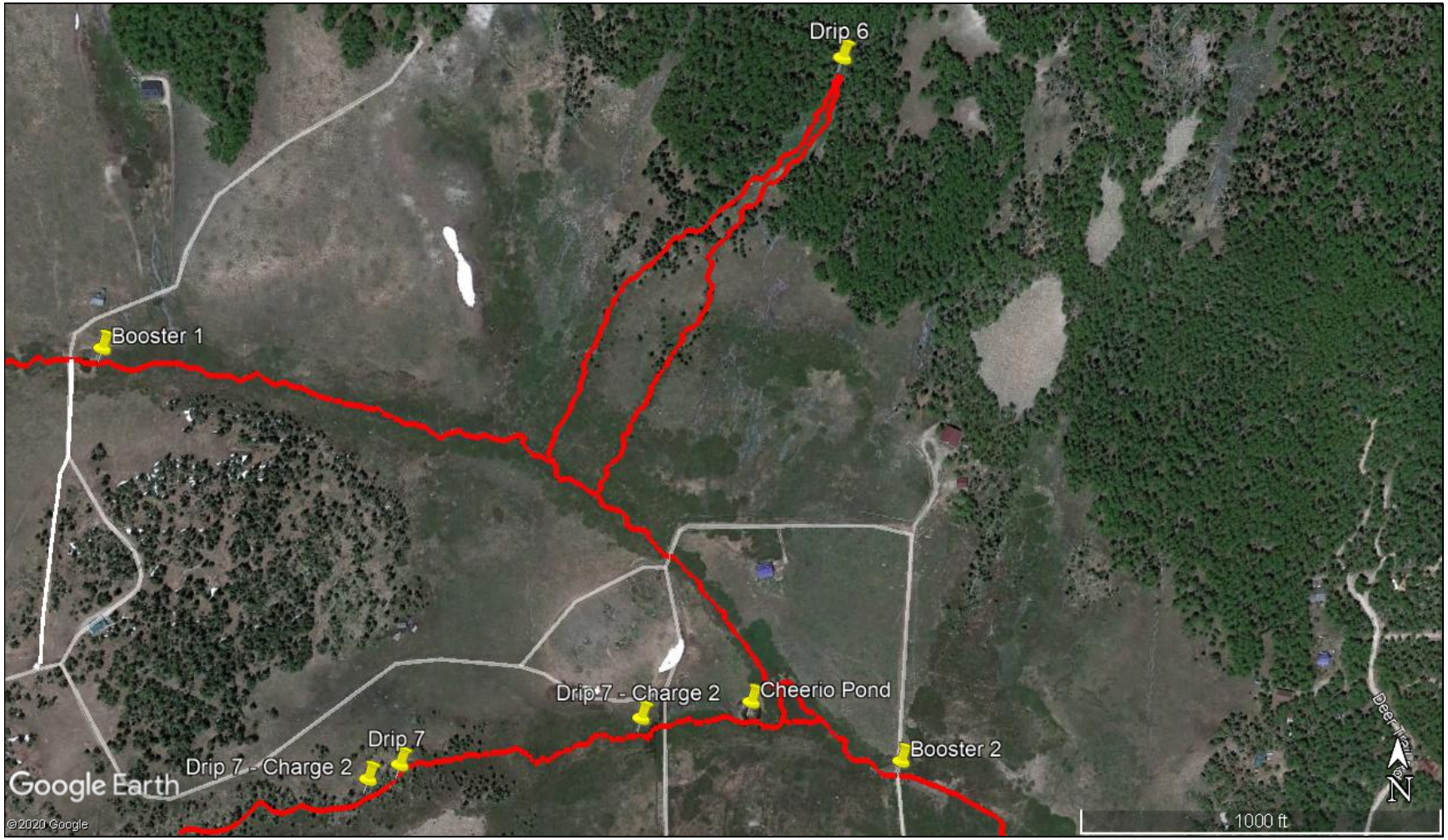

Figure 8. Locations of rotenone drip stations set in the Ireland Meadow reach of Mammoth Creek.

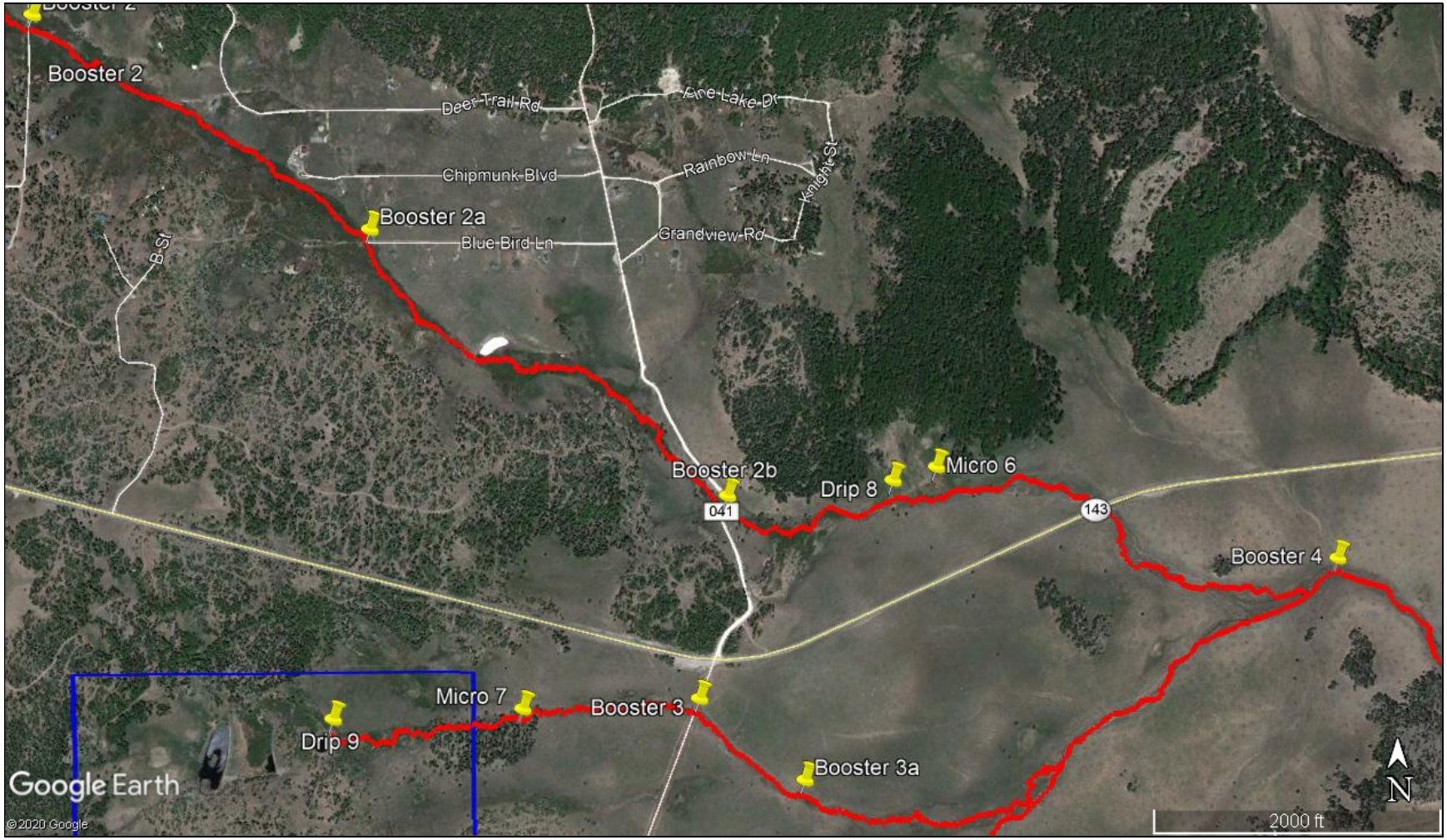

Figure 9. Locations of rotenone drip stations set in the Rainbow Meadow reach of Mammoth Creek, as well as the Harber ponds outflow.

Figure 10. Locations of rotenone drip stations set in the Red Desert reach of Mammoth Creek.

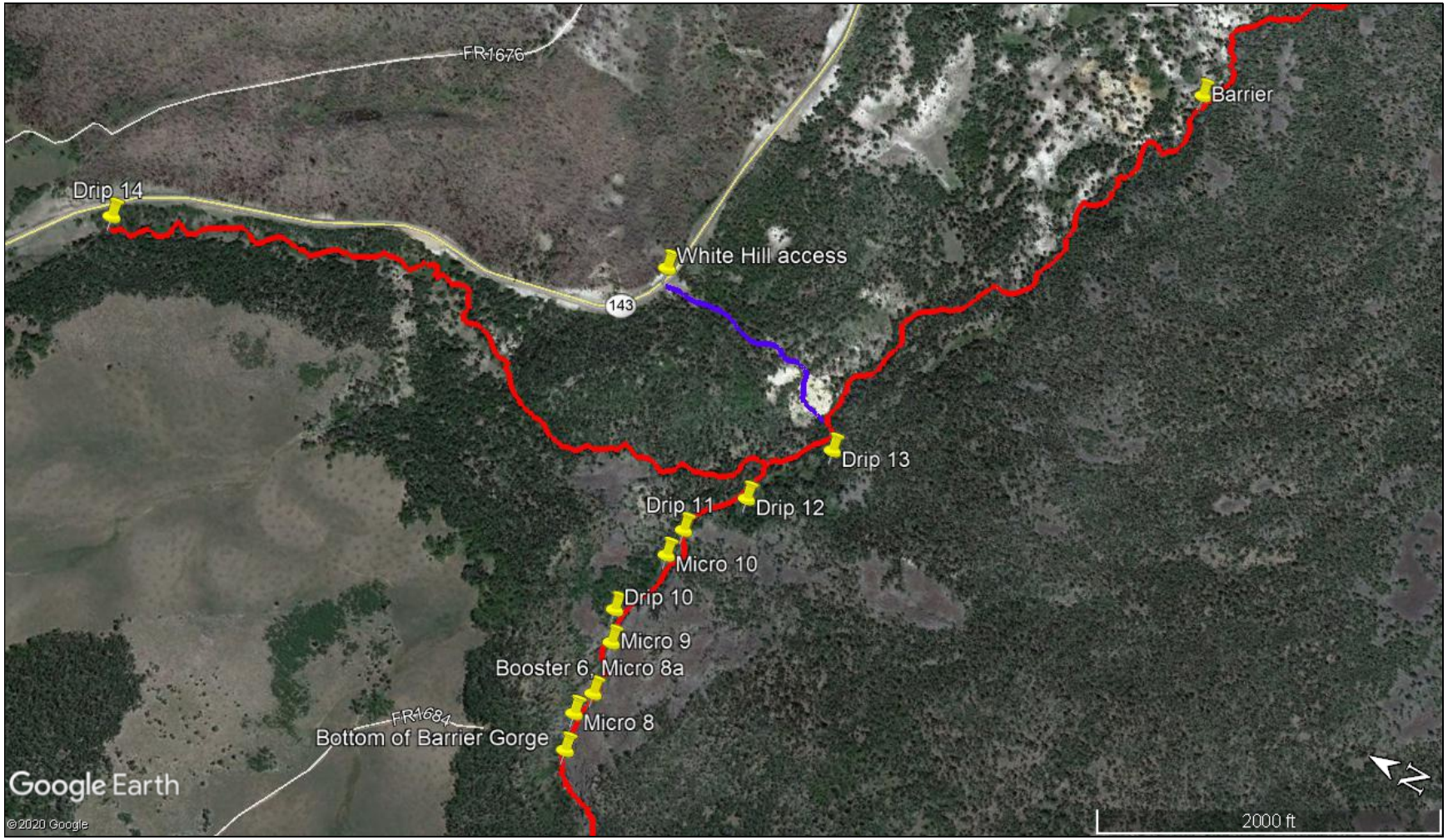

Figure 11. Locations of rotenone drip stations set in Mammoth Creek from the waterfall gorge to the upper fish barrier, as well as lower Castle Creek.

Figure 12. Detailed view of the waterfall gorge reach of Mammoth Creek, with rotenone drip stations.

Figure 13. Locations of rotenone drip stations, detox, and dry section in the reach of Mammoth Creek from the upper fish passage barrier to Mammoth Spring.

Table 1. Project personnel and assignments for chemical treatments in the Mammoth Creek drainage in 2020.

Personnel	Assignment
John L Flat, Porcupine Lake, Dead Lake: June 22-23, 2020	
Mike Hadley, UDWR SRO	Planning, recon, supervise, drips, lake pump application
Mike Golden, DNF	Planning, drips, spray lakes
MaKayla Roundy, UDWR SRO	Spray streams, lakes
Trent Utley, UDWR SRO	Spray streams, lakes
Joe Hagengruber, DNF	Spray streams, lakes
Logan Ekker, FNF	Spray streams, lakes
Nic Braithwaite, UDWR SRO	Spray lakes
Stan Beckstrom, UDWR SRO	Spray lakes
John Hudson, UDWR SRO	Spray lakes
Kevin Wheeler, UDWR WCFO	Spray lakes
Kody Callister, UDWR WCFO	Spray lakes
Izzie Speer, UDWR WCFO	Spray lakes
Reed Valley Creek: July 7, 2020	
Mike Hadley, UDWR SRO	Planning, recon, supervise, drips
Mike Golden, DNF	Drips, spray
MaKayla Roundy, UDWR SRO	Spray
Trent Utley, UDWR SRO	Spray
Joe Hagengruber, DNF	Spray
Meadow Lake isolated headwater: July 30, 2020	
Mike Hadley, UDWR SRO	Planning, recon, supervise, drips
Mike Golden, DNF	Spray
Joe Hagengruber, DNF	Spray
Meadow Lake and Creek, Harber Ponds: August 4, 2020	
Mike Hadley, UDWR SRO	Planning, recon
Mike Golden, DNF	Supervise, drips
Jens Swensen, FNF	Drips, spray
Logan Ekker, FNF	Drips, spray
Josh Verde, UDWR CRO	Drips, spray
UDWR CRO technicians (4)	Spray
Joe Hagengruber, DNF	Spray
Mitchell Peterson, UDWR SRO	Spray
Richard Hepworth, UDWR SRO	Lake application
Phil Tuttle, UDWR SRO	Lake application
MaKayla Roundy, UDWR SRO	Lake application
UDWR WCFO (6 total)	Lake shoreline spray crew
Trent Utley, UDWR SRO	Harber Ponds application
Matt Pace, FNF	Harber Ponds application

Table 1 (contd.). Project personnel and assignments for chemical treatments in the Mammoth Creek drainage in 2020.

Personnel	Assignment
Mammoth Creek: August 3-7, 2020	
Mike Hadley, UDWR SRO	Planning, recon, supervise, salvage
Mike Golden, DNF	Planning, supervise Headwater crew, drips, spray
MaKayla Roundy, UDWR SRO	Recon, drips, spray, salvage, beaver dams
Trent Utley, UDWR SRO	Recon, drips, spray, salvage, beaver dams
Joe Hagengruber, DNF	Recon, drips, spray, salvage, beaver dams
Mitchell Peterson, UDWR SRO	Recon, drips, spray, salvage, beaver dams
Phil Tuttle, UDWR SRO	Drips, salvage
Richard Hepworth, UDWR SRO	Drips, supervise Ireland Meadow crew
Jens Swensen, FNF	Drips, spray, salvage
Logan Ekker, FNF	Spray, salvage, beaver dams
Ryan Shaw, UDWR NERO	Spray
Clay Tyler, Wahweap Hatchery	Drips, spray
Kaylee Sandel, Wahweap Hatchery	Spray
Kevin Wheeler, UDWR WCFO	Drips, supervise Rainbow Meadow crew
Izzie Speer, UDWR WCFO	Spray
Nathan St Andre, UDWR SERO	Spray
Nic Braithwaite, UDWR SRO	Drips
Karen Scott, Mammoth Cr Hatchery	Salvage, tend salvaged fish, re-stock, spray, sentinel fish
Colten Brown, Mammoth Cr Hatchery	Spray
Erik Woodhouse, UDWR WCFO	Drips, spray, supervise Red Desert crew
Sarah Siefkin, UDWR WCFO	Drips, spray
Kody Callister, UDWR WCFO	Drips, spray, supervise Gorge crew
Martin Schijf, UDWR WCFO	Drips, spray
Taylor Shamo, Glenwood Hatchery	Drips, spray
Natalie Boren, UDWR NERO	Drips, spray
Austin Nardi, UDWR NERO	Spray
Bryan Engelbert, UDWR NERO	Spray
Zach Daniels, UDWR NERO	Spray
Matt Pace, FNF	Drips
Jim Whelan, FNF	Detox, supervise Lower crew
Mark Ekins, UDWR SRO	Salvage
Zane Olsen, Wahweap Hatchery	Salvage
Chuck Chamberlain, DNF	Salvage
UDWR CRO technicians (5)	Salvage
Mike Jensen, UDWR SRO	Food

Table 2. Rotenone travel time and rate in selected treated reaches.

Stream	Reach	Distance (mi)	Travel Time (hrs)	Rate (mi/hr)
John L Flat Cr	Drip 1 to Booster 1	0.33	4.2	0.075
John L Flat Cr	Booster 1 to Booster 2	0.37	4.0	0.093
Mammoth Cr	Booster 2 to Booster 2a	0.56	8.0[1]	0.070
Cheerio Pond trib	Drip 7 to beaver pond	0.16	3.3[1]	0.048
Mammoth Cr	Booster 4 to 0.5 mi above Booster 5	1.83	10.5	0.174
Castle/Mammoth	Hwy 143 to 0.6 mi above Booster 8	3.04	13.7	0.222
Mammoth Cr	Booster 8 to detox	0.40	2.5	0.160

[1] – Minimum travel time – rotenone may have arrived to reach end point much earlier.

Table 3. Chemical used during 2020 treatments in the Mammoth Creek drainage.

Date and location	Chemical and formulation	Application method	Amount of chemical used	Concentration / rate
June 22-23, 2020 John L Flat Creek	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	1.26 gal (4.76 L)	~1.5 ppm total ingredient
June 23, 2020 Porcupine Lake	Liquid rotenone, 5% active ingredient	Back pack sprayers	1.50 gal (5.68 L)	~1.5 ppm total ingredient
June 23, 2020 Dead Lake	Liquid rotenone, 5% active ingredient	Back pack sprayers and pump	5.0 gal (18.93 L)	~1.5 ppm total ingredient
July 7, 2020 Reed Valley Creek	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	1.02 gal (3.87 L)	~1.5 ppm total ingredient
July 30, 2020 Meadow Lake Cr headwater	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.40 gal (1.51 L)	~1.5 ppm total ingredient
August 4, 2020 Meadow Lake Cr	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	1.99 gal (7.54 L)	~1.5 ppm total ingredient
August 4, 2020 Meadow Lake	Liquid rotenone, 5% active ingredient	Back pack sprayers	1.50 gal (5.68 L)	~1.5 ppm total ingredient
August 4, 2020 Meadow Lake	Powder rotenone, 7.9% active ingr.	Boat mounted aspirator	220 lbs (100 kg)	~1.5 ppm total ingredient
August 4, 2020 Harber private ponds	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.34 gal (1.30 L)	~1.5 ppm total ingredient
August 4-5, 2020 Mammoth Creek	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	7.98 gal (30.22 L)	~1.5 ppm total ingredient
August 4-5, 2020 Castle Creek	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	2.16 gal (8.16 L)	~1.5 ppm total ingredient
August 4-5, 2020 Harber ponds outflow	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.81 gal (3.08 L)	~1.5 ppm total ingredient
August 5-6, 2020 Mammoth Creek	Potassium permanganate	Auger	91.3 lbs (41.5 kg)	22.1 g/min (mean)

Table 4. Length of stream and area of lakes treated with rotenone in the Mammoth Creek drainage in 2020.

Stream	**Length (mi)**	**Length (km)**
John L Flat Creek	2.52	4.06
Reed Valley Creek	2.76	4.44
Meadow Lake Creek	2.71	4.36
Harber Ponds outflow	1.23	1.98
Castle Creek	1.19	1.92
Mammoth Creek	11.56	18.62
Total	**21.97**	**35.38**
Lake	**Area (ac)**	**Area (ha)**
Porcupine Lake	1.15	0.47
Dead Lake	1.85	0.75
Meadow Lake	12.00	4.86
Harber Middle Pond	0.13	0.05
Harber Lower Pond	0.18	0.07
Total	**15.31**	**6.20**