Mad River Continuous Temperature Monitoring Study
2014 Report

A project of Mad River Alliance, with assistance and cooperation by Green Diamond Resource Company, Blue Lake Rancheria, Six Rivers National Forest, Mad River Youth Conservation Corps and community volunteers

05.15.15

Table of Contents

Introduction

The Mad River watershed is located in northern California, and flows roughly 100 miles northwest from its source in the southern Klamath Mountains above Ruth Lake in Trinity County, through Humboldt County; meeting the Pacific Ocean a few miles north of Humboldt Bay. The watershed drains about 500 square miles of steep, forested mountains and rolling oak-grassland hills, and is fairly narrow, averaging six miles wide through the middle-upper canyon. The Mad River watershed hosts a variety of North American wildlife, including 28 native freshwater and estuarine fish species: Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead and resident rainbow trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and the occasional sockeye salmon (*O. nerka*), and chum salmon (*O. keta*). Native resident fish include: Pacific lamprey (*Entosphenus tridentata*), prickly sculpin (*Cottus asper*), coast range sculpin (*C.aleuticus*), Sacramento sucker (*Catostomas occidentalis*), Humboldt sucker (*Catostomas occidentalis humboldtianus*), three-spine stickleback (*Gasterosteous aculeatus*), longfin smelt (*Spirinchus thaleichthy*), starry flounder (*Platichthys stellatus*),eulachon (*Thaleichthys pacificus*), tidewater gobi *(Eucyclogobius newberryi)*, staghorn sculpin *(Leptocottus armatus)*, night smelt (*Spirinchus starski)*, buffalo sculpin (*Enophrys bison)*,cabezon *(Scorpaenichthys marmoratus*), penpoint gunnel *(Apodichthys flavidus)*, saddelback gunnel (*Pholidae ornate)*, Pacific herring (*Culpea pallasii)*,black rockfish (*Sebastes melanops*),copper rockfish (*Sebastes courinus*),Bay pipefish (*Syngnathus loptorhyncus*),speckled sanddab (*Citharichthys stigmaeus*), and shiner surfperch (*Cymatogaster aggregata*). Mad river also serves as the source of drinking water for 88,000 Humboldt County residents served by the Humboldt Bay Municipal Water District (HBMWD). It is important to note, during the low flow season, typically June through October, Mad River flows are augmented by water releases via the powerhouse at R.W. Matthews Dam, which impounds Ruth Lake. HBMWD owns and manages water released from Ruth Lake at R.W. Mathews Dam. Little is known about how these releases might affect water temperature.

Mad River provides habitat for all life stages of 3 salmonid species that are listed as threatened under the Federal Endangered Species Act (ESA): Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon *(O. kisutch)*, and steelhead trout *(O.mykiss)*. Other salmonids documented in Mad River include: coastal cutthroat trout (*O. clarki clarki*), and occasionally *sockeye salmon (O. nerka)* and chum salmon (*O. keta*).[1] Mad River also provides critical habitat for protected estuarine fish species: long fin smelt (*Spirinchus thaleichthys)*, listed as threatened under California ESA; eulachon or candle fish *(Thaleichthys pacificus)*, and tidewater gobi *(Eucyclogobius newberryi)*, both listed as threatened under Federal ESA. Other species of interest include: Pacific lamprey *(Entosphenus tridentatus)*, green sturgeon *(Acipenser medirostri)*, and freshwater mussels (*Anodonta californiensis*, and *A. nuttalliana*).

Though not the focus of this report, it is of special importance to note critical temperature thresholds for salmonids while considering these data. In Brett (1952), "Lethal limits of high and low temperatures were determined for the young of five species of Pacific salmon, the spring (*Oncorhynchus tshawytscha*), the pink (*O. gorbuscha*), the sockeye (*O. nerka*), the chum (*O. keta*) and the coho (*O. kisutch*)." Brett (1952) reports, "no species could tolerate temperatures

[1] Mad River Watershed Assessment Prepared for Redwood Community Action Agency
Prepared by Stillwater Sciences 850 G Street, Suite K Arcata, CA, 95521

exceeding 25.1°C when exposed for one week." Welsh et al. (2001) found in Mattole river tributaries, "temperature regimes in the warmest tributaries containing juvenile coho salmon had maximum weekly maximum temperatures of 18.0°C or less." No study has determined the thermal regimes in the Mad River mainstream or its tributaries for supporting salmonids, but it is important to recognize thermal regimes in any stream supporting salmonids may be less than the critical thermal maxima derived from short term laboratory and field experiments (e.g. Konecki et al. 1995; Brett 1952) depending on whether available food resources are sufficient to meet the metabolic demands at higher water temperatures.

There is no doubt that Mad River watershed managers face many challenges in their efforts maintain and restore a healthy watershed. In 1992, the Environmental Protection Agency (EPA) added Mad River to Clean Water Act Section 303(d) List of Impaired Waters due to elevated sedimentation/siltation and turbidity. The North Coast Regional Water Quality Control Board NCRWQCB identified water temperature as an additional impairment to the watershed in 2006.[2]

Effects of climate change on average stream temperatures and related effects on biological life are critical issues all watershed managers must be prepared to monitor and plan for, as ambient temperatures are projected to rise in the coming decades. The California Department of Water Resources (DWR) recognized in 2007, "Climate change is already impacting California's water resources. In the future, warmer temperatures, different patterns of precipitation and runoff, and rising sea levels will profoundly affect the ability to manage water supplies and other natural resources." This year, National Oceanic and Atmospheric Administration (NOAA) State of the Climate, Global Report 2015 stated: "During January–March, the globally-averaged land surface temperature was 2.86°F (1.59°C) above the 20th century average. This was the highest for January–March in the 1880–2015 record, surpassing the previous record of 2002 by 0.09°F (0.05°C)."[3]

Historically, there have been few independent efforts to record and evaluate water temperatures in Mad River. Lewis et al. (2001) compiled a report for the Forest Science Project (FSP) in 2000, entitled: "Regional Assessment of Stream Temperatures across Northern California and Their Relationship to Various Landscape-Level and Site-Specific Attributes." In their report, Lewis et al. compared Mad River stream temperatures from, "a site located on the North Fork of the Mad River near Korbel, CA, the periodic maximum water temperature in 1959 was 22°C with a maximum air temperature on that day of 17.8°C (Figure 1 1.12). Nearly forty years later, at a FSP site located about 1700 m downstream from the USGS site, the highest daily maximum water temperature was 23°C." Lewis and his team report there was a 1°C increase in the highest daily temperature from 1959 to 1998.
Green Diamond Resource Company (GDRC, formerly Simpson Timber Company) has collected summer time water temperature data in several tributaries of Mad River including: Boulder Creek 1994 - 2014, Maple Creek 1994 - 2014, Cañon Creek 1994 - 2014, Lindsay Creek 1994 - 2014, Dry Creek 1994-2014, Devil Creek 1997-2013, Simpson Creek 1997-2014, Mill Creek 1997-2014, Bug Creek 1997 – 2003, Deer Creek 1998 – 2003, Coyote Creek, 1999 – 2003, 1999 – 2014, and Boundary Creek 2007 – 2014 (personal communication Matt House 2015). In addition to FSP,

[2] Mad River Watershed Assessment

[3] NOAA State of the Climate, Global Report. 2015 http://www.ncdc.noaa.gov/sotc/global/2015/3

USGS and Green Diamond temperature data, Dennis Halligan collected temperatures in Hall and Quarry Creek from 1995 till 1998 for the Fisheries Monitoring Program for Gravel Extraction operations on the Mad River. No attempt has been made to compile or compare these studies to date, nor has any known attempt been made to create and implement a watershed-wide sampling plan for Mad River and key tributaries until 2014, when this study was developed.

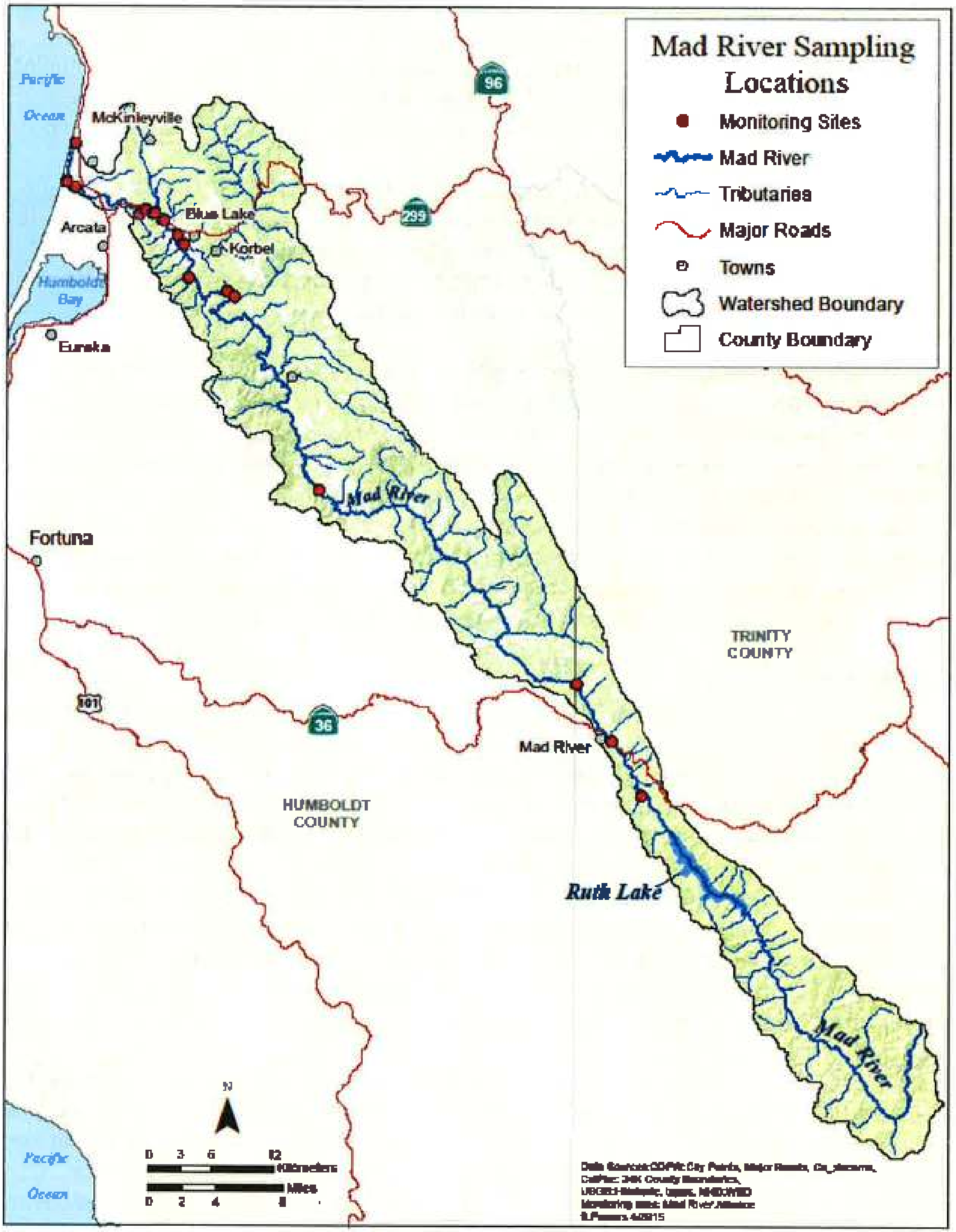
The goal of the Mad River Continuous Temperature Monitoring Study (MRCTMS) is to sample water temperatures in more locations than have been historically sampled, and to gain greater insight regarding stream temperatures at as many locations as possible in the mainstem and tributaries. This first year of the study is an attempt to begin a comprehensive approach to stream temperature monitoring in the Mad River watershed.

To accomplish our goal, Mad River Alliance (MRA) worked in cooperation with the Blue Lake Rancheria (BLR), Green Diamond Resource Company (GDRCo), and Six Rivers National Forest (6RNF) with a group from Youth Conservation Corps (YCC), to deploy 20 HOBO temperature loggers throughout the watershed from June-October 2014. This preliminary report is our attempt to document and understand how water temperatures in Mad River may be affected by both managed and natural conditions by collecting and providing temperature data for comparison to historical data for long term comprehensive trend monitoring. One goal behind the MRCTMS is to create a repeatable, annual effort to establish a long-term data set to understand trends in stream temperature throughout the Mad River watershed.

Methods & Materials

MRCTMS consists of 2 integral parts: guiding documents and physical equipment to collect and process collected data. Guiding documents consist of a Memorandum of Understanding (MOU) between parties, which outlines roles and responsibilities for each participating party; a Sampling Plan (SP) and Quality Assurance Project Plan (QAPP) which explains the methods and materials used to implement the calibration, deployment, and retrieval of HOBO loggers, data processing and reporting related to this study. The physical equipment consists of HOBO continuous temperature loggers, PVC tubes and galvanized pipe end caps used to create secure housings for HOBOs, and braided wire cable to secure HOBOs to their respective sampling sites; a field record book and reference photographs to give proper guidance to the deployment and retrieval sites of HOBOs and collect metadata about the deployment/retrieval sites. The SP and QAPP as well as the transcribed field notes are included in this report in the appendix.

Site selection was completed using local knowledge and aided by satellite mapping software. Using known available access points and known holding habitats for salmonid species, a priority list of accessible sites was created. Public access is extremely limited in the stretch of Mad River between the towns of Mad River and Blue Lake, so some desired monitoring sites in the mainstem as well as tributaries were unable to be accessed for the purpose of this study. With available public access points, coverage of the entire basin, between R.W. Matthews Dam and the mouth of Mad River was achieved. See maps below for actual deployment sites.



Mad River Sampling Locations
Monitoring Sites
Mad River
Tributaries
Major Roads
Towns
Watershed Boundary
County Boundary
Pacific Ocean
McKinleyville
Arcata
Blue Lake
Korbel
Humboldt Bay
Eureka
Fortuna
96
299
101
36
Mad River
Mad River
TRINITY COUNTY
HUMBOLDT COUNTY
Ruth Lake
Mad River
Pacific Ocean
N
0 3 6 12 Kilometers
0 2 4 8 Miles


Middle Mad River Temperature Monitoring Locations
Temperature Monitoring Sites
Mad River
Tributaries
Towns
Major Roads
Mad River Middle Subwatershed
Watershed Boundary
County Boundary
Pilot Creek
Mad River
County Line Creek
Hastings Creek
Lamb Creek
Sunrise Meadow Bridge
Cherry Glade Creek
Grace Cr.
Hale Creek
Ruth Lake
36
TRINITY COUNTY
HUMBOLDT COUNTY
N
0 1 2 4 Kilometers
0 0.75 1.5 3 Miles


Lower Mad River Temperature Monitoring Locations
Temperature Monitoring Sites
Mad River
Tributaries
Towns
Major Roads
Lower Mad Subwatershed
Watershed Boundary
Pacific Ocean
Widow White Creek
Fieldbrook
McKinleyville
Boat Ramp
Mill Creek
Lindsay Creek
North Fork Mad River
Hall Cr.
Mill Creek
Noisy Creek
Hammond Trail Bridge
Blue Lake
Powers Creek
Arcata
Warren Creek
Korbel
Humboldt Bay
Puter Creek
Vincent Creek
Cowan Creek
Mad River
101
299
Eureka
Maple Creek
Goodman Prairie Creek
Graham Creek
Madrone Creek
Cowan Creek
N
0 1.5 3 6 Kilometers
0 1 2 4 Miles
Data Sources:CDFW:City Points, Major Roads, Ca_streams,
CalFire: 24K County Boundaries,
USGS:Hillshade, topos, NHD:WBD Modified
Monitoring sites: Mad River Alliance
S.Powers 4/2015

Implementation

16 of the HOBO deployments occurred over the course of 3 days: July 15-17th, 2014. This includes all sites from middle Mad River to the mouth. Due to unseen logistical reasons, 3 HOBOs in the upper watershed were not deployed until August 4th and 5th, 2014. 1 One HOBO was not deployed at all, due to access issues.

A HOBO for one site, Mad River at HWY 36 Bridge was accidentally switched with another identical HOBO logger owned by 6RNF. It was calibrated according to manufacturer's specifications and there is no concern of data inaccuracy for this site.

To assist in the retrieval process, detailed field notes and photographs were taken, and GPS coordinates were collected. During the deployment and retrieval periods, metadata about site conditions were also gathered. These metadata fields include:

- People deploying/retrieving HOBOs
- Habitat type
- Canopy cover
- Physical description of site conditions
- Presence/absence of birds/wildlife/fish species/algae

All 19 HOBOs were successfully retrieved from October 11-13th.

It is of special importance to note that these deployments and retrievals were completed by a number of volunteers that represent different agencies, Tribes, and organizations, including:

- Jacob Pounds, BLR and MRA
- Dave Feral, MRA
- Matt House, GDRC
- Karen Kenfield, 6RNF
- Leslie Wolff, NOAA
- Michelle Gilroy California Department of Fish and Wildlife
- Carolyn Cook
- Mad River YCC crew
- Hollie Hall
- Steven Lazar

Data

For the purpose of this study, HOBO temperature loggers were used to collect the data every 1 hour and 20 minutes. These instruments were calibrated to manufacturer's specifications and in accordance to GDRCo's aquatic monitoring protocols. Although there are many different types and manufacturers of continuous temperature recording technology, GDRCo offered 20 HOBOs that had previously been used for their own required monitoring efforts. GDRCo also offered to download and process the data in accordance with their aquatic monitoring protocols to assist with this study. Without this key assistance, this study would not have been possible.

Data were downloaded off of each individual HOBO and processed with the proprietary HOBOware software by Onset. For each site, a visual (graph) report summary was created, and GDRC provided both raw and trimmed data summaries in .csv format in Microsoft Excel spreadsheets. All the trimmed data spreadsheets are included in the appendix to this document, and the visual data summaries are in the Findings section.

Findings

The data show that most of the mainstem sites were relatively warm, with the highest single temperature recorded at the site above Puter Creek on October 4, 25.09 degrees Celsius(C). The warmest 7 day average period was above 20°C at 11 of 19 sites.

The following is a summary of the maximum and average temperatures for all sites, and graphic breakdowns of 7-day average maximum, minimum, and average temperatures collected for each site.

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Summary Table Legend

Fig #	The figure number that corresponds the row of data to the temperature profile.
Site Name	The name of the monitoring site.
Site ID	A unique number given to the monitoring site.
CC	Channel classification (CC) of the monitoring site where I-F = Class I Fish Bearing, I-D = Class I Domestic Water Source, I-FD = Class I Fish Bearing/Domestic Water Supply, I-R = Class I Restorable, II-FPR = Class II Forest Practice Rules, II-1 = Class II 1st Order, II-2 = Class II 2nd Order, II-S = Class II Small, II-L = Class II Large, III = Class III, IV = Class IV, or Unclassified.
MI (hrs)	Measurement interval (MI): the time interval (hours) between temperature measurements.
From Date	The date (mm/dd/yyyy) when the monitoring period started.
To Date	The date (mm/dd/yyyy) when the monitoring period ended.
# Days	The number of days temperature was recorded during the monitoring period.
N	The sample size for temperature readings collected during the monitoring period.
T_{avg}	The average temperature for the monitoring period. Calculated using all records collected.
T_{SD}	The standard deviation of T_{avg}
T_{var}	The variance of T_{avg}
T_{min}	The minimum temperature recorded during the monitoring period.
T_{min} Days	The total number of calendar days in the monitoring period where the T_{min} occurred.
T_{min} Date	The date (mm/dd) when the first occurrence of the T_{min} was recorded.
T_{max}	The maximum temperature recorded during the monitoring period.
T_{max} Days	The total number of calendar days in the monitoring period where the T_{max} occurred.
T_{max} Date	The date (mm/dd) when the last occurrence of the the T_{max} was recorded.
Min After Max	The minimum temperature following the maximum temperature on the T_{max} date.
$7DMAVG_{(A)}$	The highest 7-day moving average of all recorded temperatures. This statistic is synonymous with Mean Weekly Average Temperature (MWAT), Method A (Ferraro 1976).
$7DMAVG_{(A)}$ Date	The central date (mm/dd, i.e., 4th day) in the last 7-day period when the $7DMAVG_{(A)}$ was calculated.
$7DMAVG_{(A)}$ Days	The total number of 7-day periods where the $7DMAVG_{(A)}$ occurred for the monitoring period.
$7DMAVG_{(N)}$	The highest 7-day moving average of all recorded temperatures (N is based on the recording interval).
$7DMAVG_{(N)}$ Date	The central date (mm/dd, i.e., 4th day) in the last 7 day period when the $7DMAVG_{(N)}$ was calculated.
$7DMAVG_{(N)}$ Days	The total number of 7-day periods where the $DMAVG_{(N)}$ occurred for the monitoring period.
7DMMX	The last occurrence of the highest 7-day moving average of the maximum daily temperatures. This statistic is synonymous with Maximum Weekly Maximum Temperature (MWMT, Walsh et. al., 2001).
7DMMX Date	The central date (mm/dd, i.e., 4th day) in the period used to calculate 7DMMX
7DMMX Days	The total number of 7-day periods where the 7DMMX occurred for the monitoring period.

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Temperature Monitoring Summary Report

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Fig #	Site Name	Site ID	CC	MI (hrs)	From Date	To Date	# Days	N	Tavg	Tsd	Tvar	Tmin	Tmin Days	Tmin Date	Tmax	Tmax Days	Tmax Date	Min After Max	7D MAVG (A)	7D MAVG (A) Date	7D MAVG (A) Days	7D MAVG (B)	7D MAVG (B) Date	7D MAVG (B) Days	7D MMX	7D MMX Date	7D MMX Days
1	CANONCK	10000657		1.20	7/16/2014	8/26/2014	42	840	15.70	0.48	0.23	14.70	1	07/26	17.51	1	08/23	14.96	16.13	08/22	1	16.13	08/21	1	17.10	08/23	1
2	HALLCK	10000658		1.20	7/10/2014	10/11/2014	88	1760	18.97	1.93	3.72	13.64	1	09/26	22.15	1	08/18	20.79	21.47	08/20	1	21.48	08/19	1	21.87	08/20	1
3	LINDSAYCK	10000659		1.20	7/16/2014	10/11/2014	88	1760	15.93	1.10	1.20	13.14	1	09/14	17.96	1	08/20	17.01	17.25	08/18	1	17.25	08/18	1	17.76	08/18	1
4	MRBRIDGE	10000661		1.20	7/17/2014	10/11/2014	87	1740	18.86	1.92	3.70	15.64	1	10/02	24.32	1	07/29	18.91	20.80	07/31	1	20.84	07/29	1	23.91	07/28	1
5	MRCOUNTYLINE	10000663		1.20	8/6/2014	10/10/2014	66	1320	18.14	1.50	2.25	12.51	1	10/10	19.37	1	08/11	17.18	17.94	08/09	1	17.94	08/09	1	18.88	08/09	1
6	MRESSEX	10000664		0.20	7/16/2014	10/11/2014	88	10560	19.31	1.84	3.39	15.18	1	09/25	23.74	1	07/25	17.23	20.57	08/18	1	20.60	08/17	1	23.29	07/27	1
7	MRHALF	10000665		1.20	8/8/2014	10/10/2014	64	1280	21.05	1.57	2.46	17.18	1	10/07	26.70	1	08/16	20.27	22.43	08/15	1	22.43	08/14	1	25.15	08/18	1
8	MRHALL	10000666		1.20	7/16/2014	10/11/2014	88	1760	19.51	1.99	3.98	15.27	1	10/01	24.24	1	07/28	18.25	20.64	08/18	1	20.68	08/17	1	24.09	07/28	1
9	MRLINDSAY	10000668		1.20	7/19/2014	10/10/2014	84	1680	19.44	1.86	3.47	15.44	2	10/01	23.83	1	07/31	18.39	20.63	08/16	1	20.67	08/17	1	23.55	07/29	1
10	MRMILL	10000669		1.20	7/17/2014	10/17/2014	93	1860	19.71	1.73	3.00	12.03	1	10/13	24.03	1	07/26	20.27	21.51	07/23	1	21.54	07/22	1	23.55	07/28	1
11	MRPOWERS	10000670		1.20	7/16/2014	10/11/2014	88	1760	18.63	2.93	8.60	13.86	2	10/07	24.20	1	07/31	18.91	21.14	08/17	1	21.19	08/17	1	23.90	08/17	1
12	MRPUTER	10000671		1.20	7/17/2014	10/10/2014	86	1720	20.82	1.90	3.62	16.25	1	10/04	25.09	1	07/31	21.10	22.75	07/31	1	22.75	07/30	1	24.89	07/31	1
13	MRSUNRISEB	10000677		0.50	8/5/2014	10/10/2014	67	3216	14.02	1.22	1.49	11.69	1	09/05	16.46	1	08/07	11.88	14.41	08/18	1	14.41	08/17	1	16.26	08/18	1
14	MRSWINGB	10000672		1.20	7/22/2014	10/12/2014	83	1660	19.74	2.37	5.60	13.93	1	10/12	24.65	1	07/28	21.34	22.86	07/31	1	22.87	07/30	1	24.46	07/31	1
15	MRVINCENT	10000673		1.20	7/10/2014	10/9/2014	92	1840	20.90	1.93	3.73	16.49	1	10/04	25.21	1	07/31	20.98	22.97	07/31	1	22.98	07/31	1	24.96	07/31	1
16	RMRBOATR	10000674		1.20	7/17/2014	10/12/2014	88	1760	17.60	1.10	1.21	15.70	1	10/11	21.75	1	07/20	18.58	19.02	07/23	1	19.02	07/22	1	20.56	07/22	1
17	WARRENCK	10000675		1.20	7/16/2014	10/11/2014	88	1760	13.45	0.78	0.60	11.32	1	09/13	15.03	1	09/24	13.86	14.33	08/16	1	14.33	08/18	1	14.57	08/18	1
18	WWCK	10000676		1.20	7/17/2014	10/12/2014	88	1760	13.45	0.56	0.31	11.88	1	09/13	17.03	1	09/24	14.29	14.43	09/24	1	14.43	09/23	1	14.97	09/24	1

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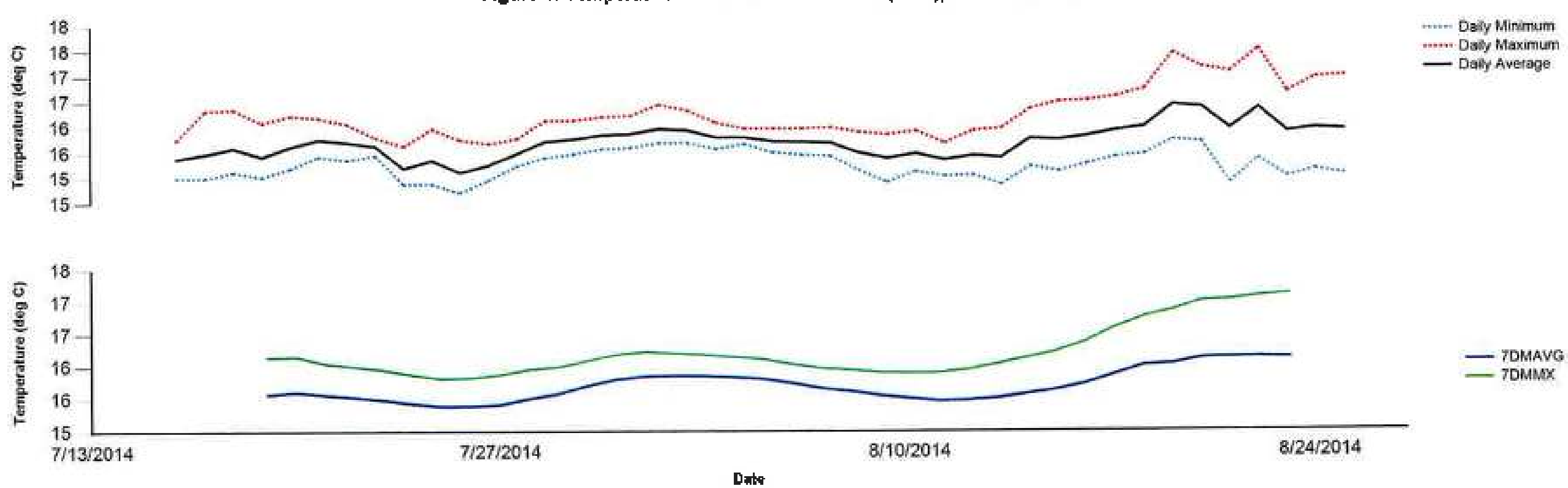
Figure 1: Temperature Profiles for CANONCK (2014), Site: 10000657



Temperature Monitoring Summary Report

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Figure 2: Temperature Profiles for HALLCK (2014), Site: 10000658

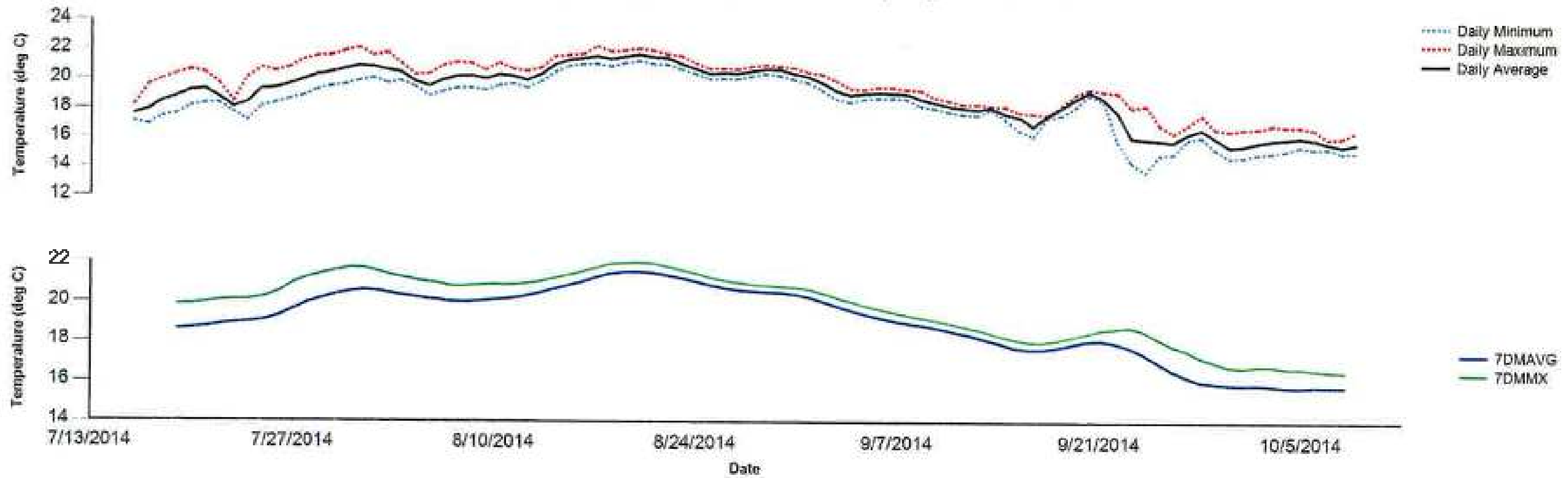


Figure 3: Temperature Profiles for LINDSAYCK (2014), Site: 10000669

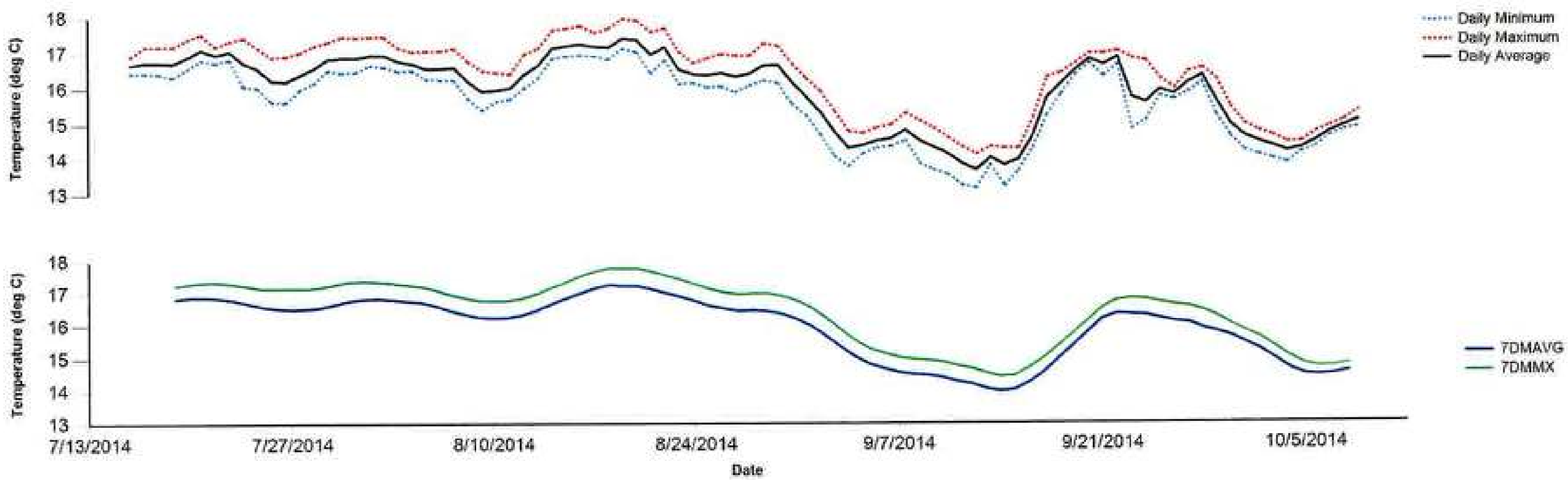


Figure 4: Temperature Profiles for MRBRIDGE (2014), Site: 10000651

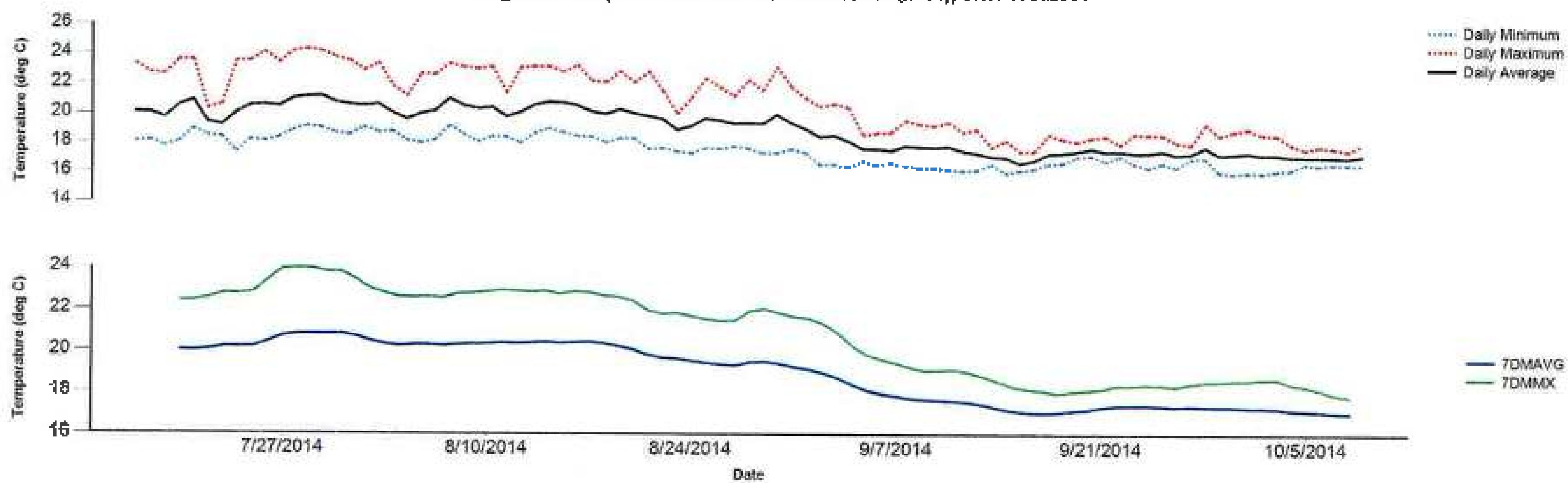
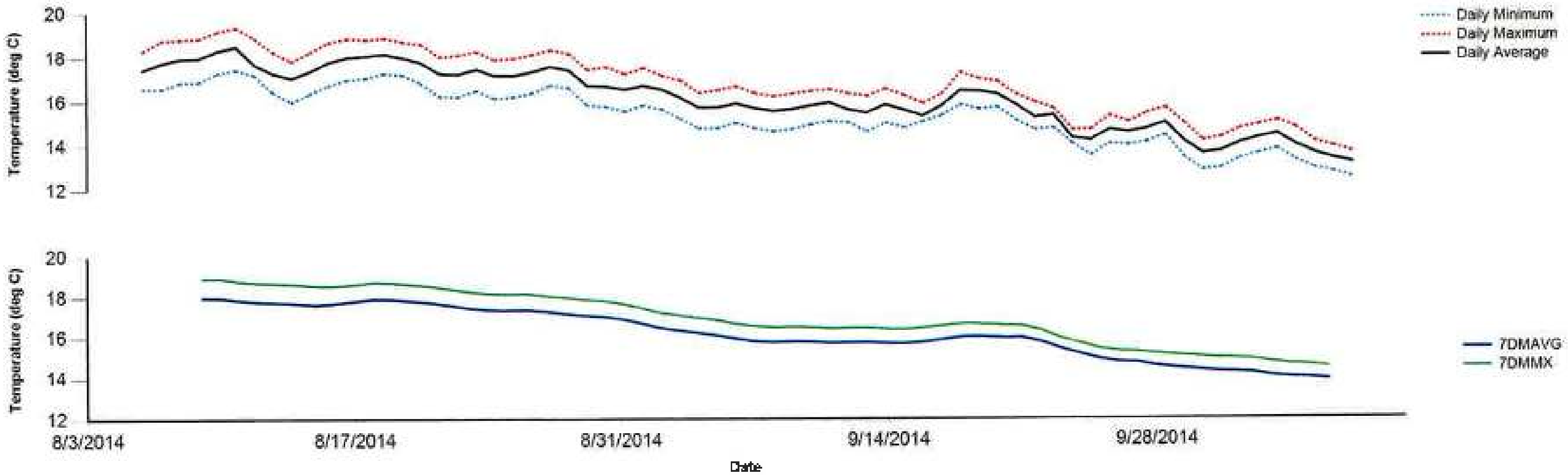


Figure 5: Temperature Profiles for MRCOUNTYLINE (2014), Site: 10000653



Temperature Monitoring Summary Report

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Figure 6: Temperature Profiles for MRESSEX (2014), Site: 10000684

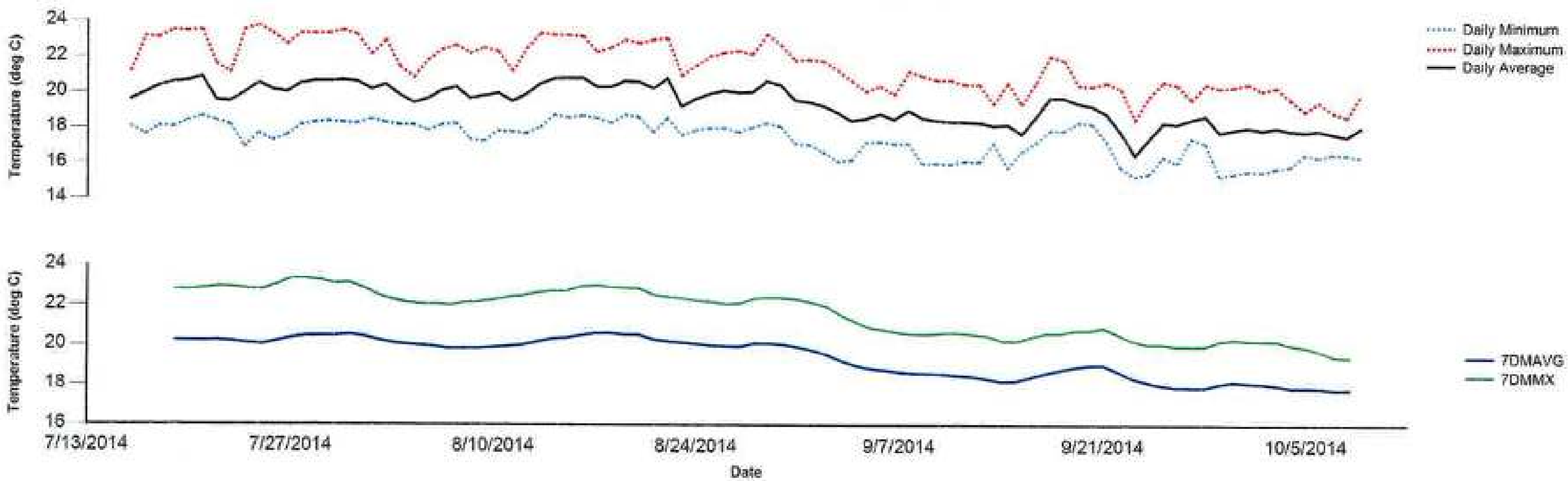
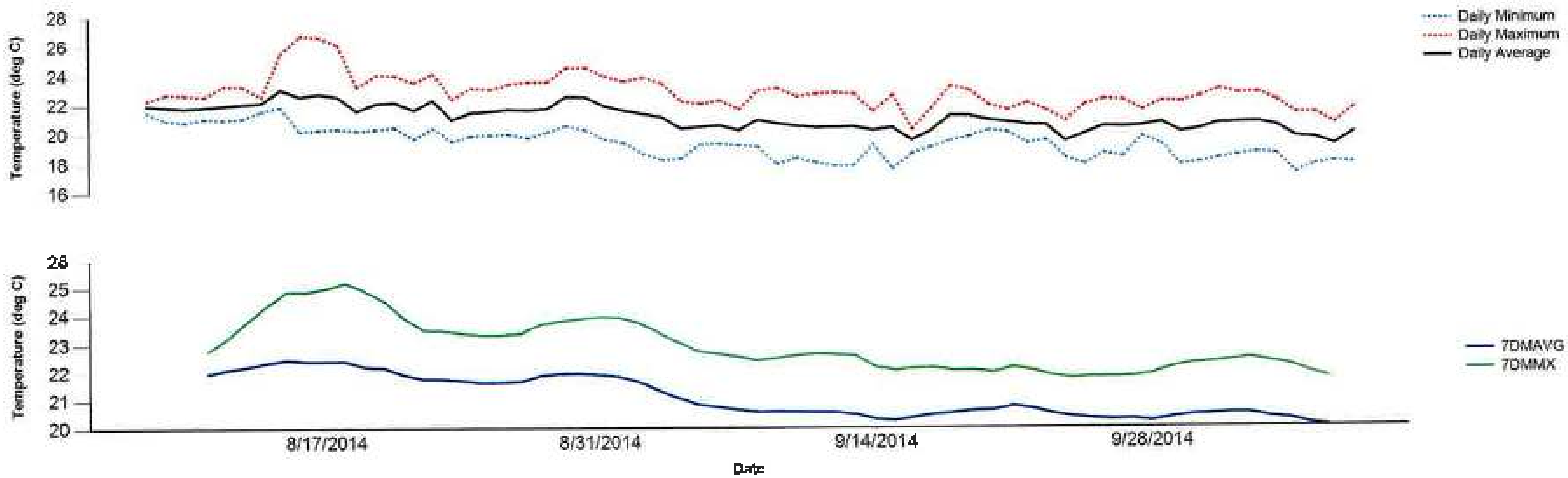


Figure 7: Temperature Profiles for MRHALE (2014), Site: 10000865



Temperature Monitoring Summary Report

GREEN DIAMOND RESOURCE COMPANY

Figure 8: Temperature Profiles for MRHALL (2014), Site: 10000666

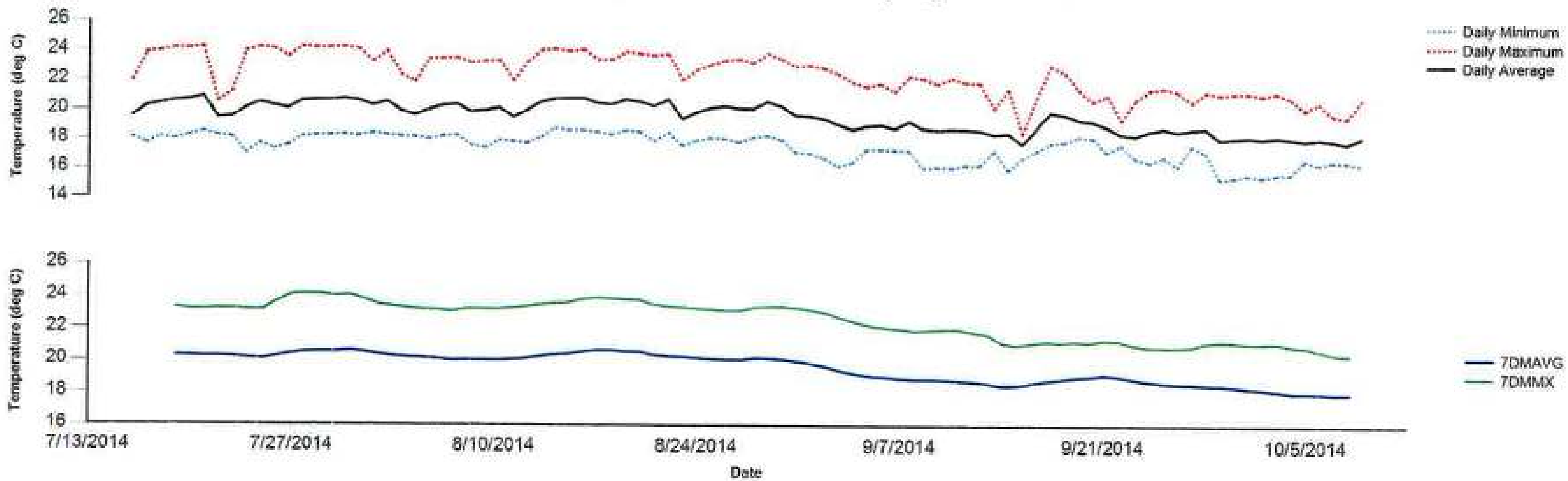


Figure 9: Temperature Profiles for MRLINDSAY (2014), Site: 10000868

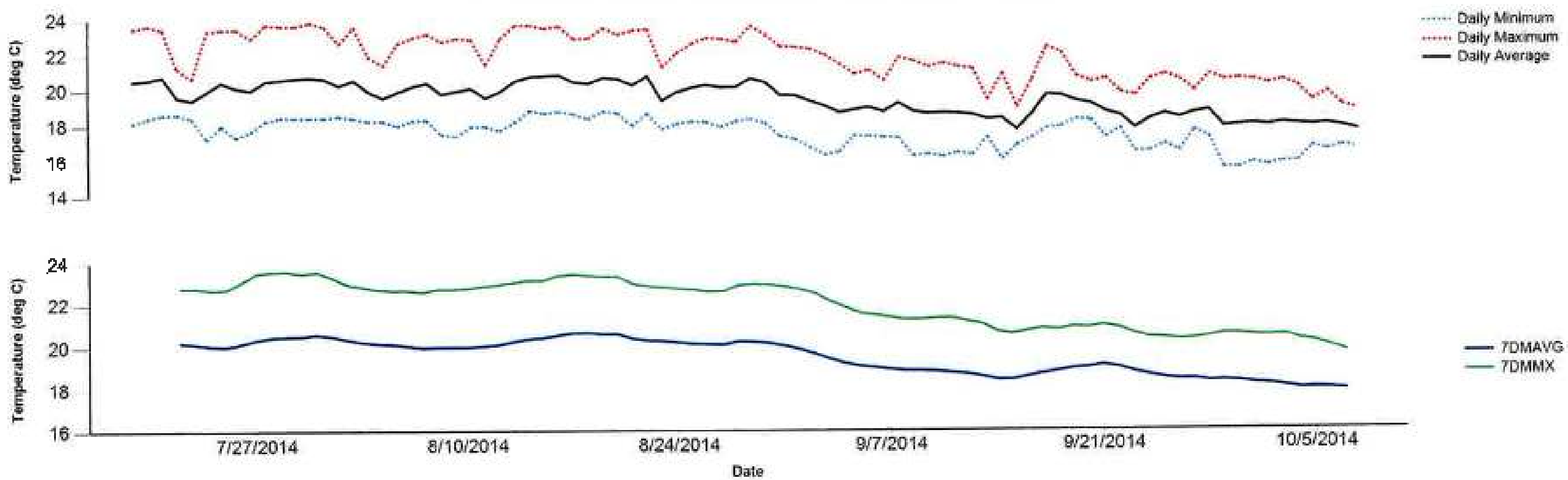
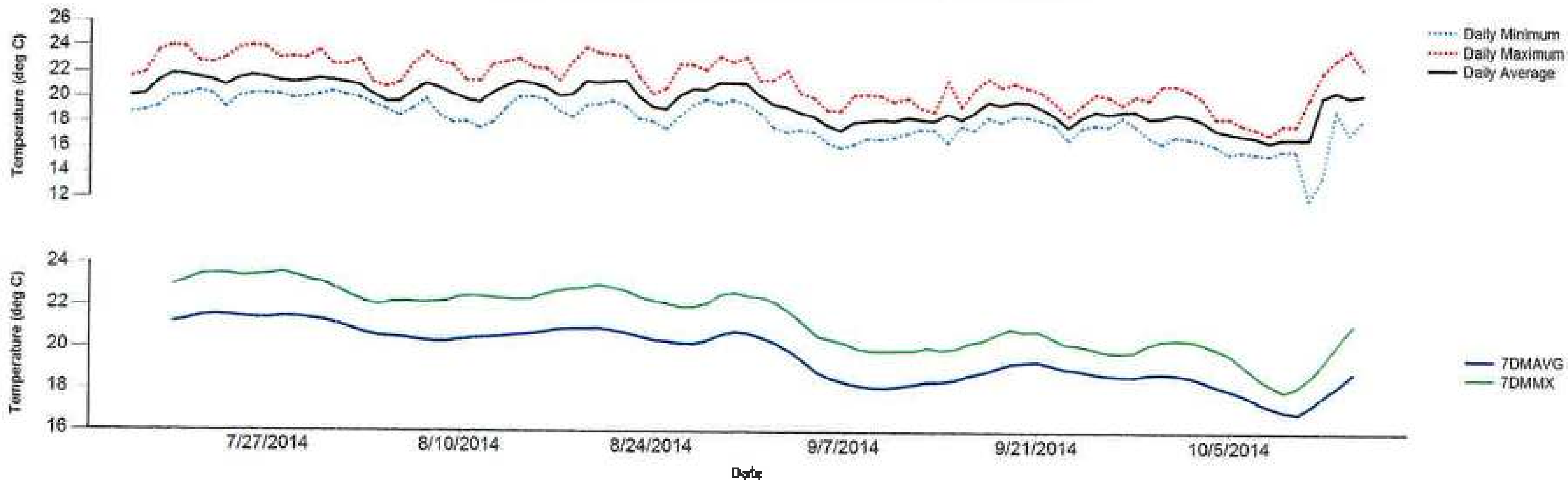


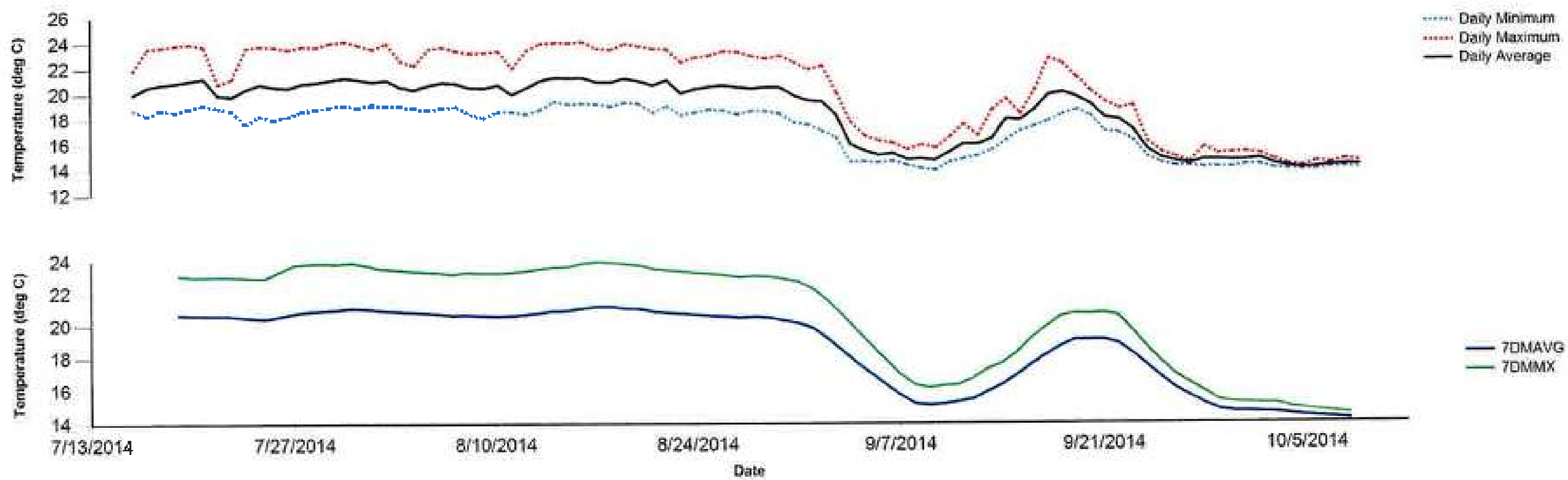
Figure 10: Temperature Profiles for MRMILL (2014). Site: 10000669



Temperature Monitoring Summary Report

GREEN DIAMOND RESOURCE COMPANY

Figure 11: Temperature Profiles for MRPOWERS (2014), Site: 10000670



Temperature Monitoring Summary Report

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Figure 12: Temperature Profiles for MRPUTER (2014), Site: 10000671

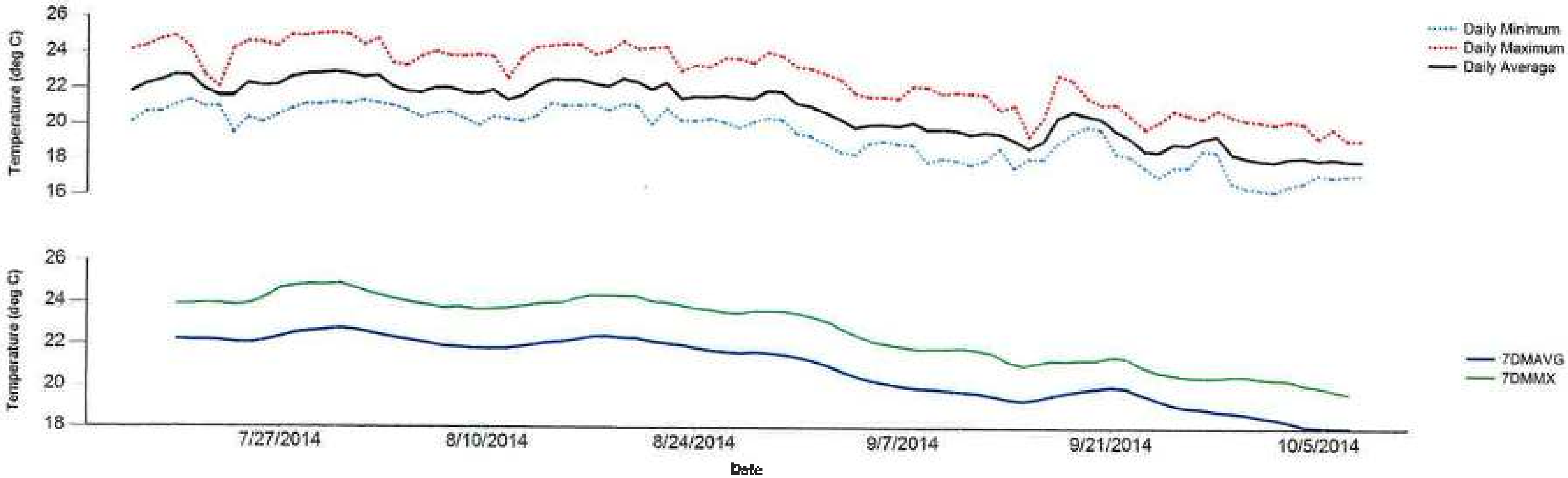


Figure 13: Temperature Profiles for MRSUNR/SEB (2014), Site: 10000877

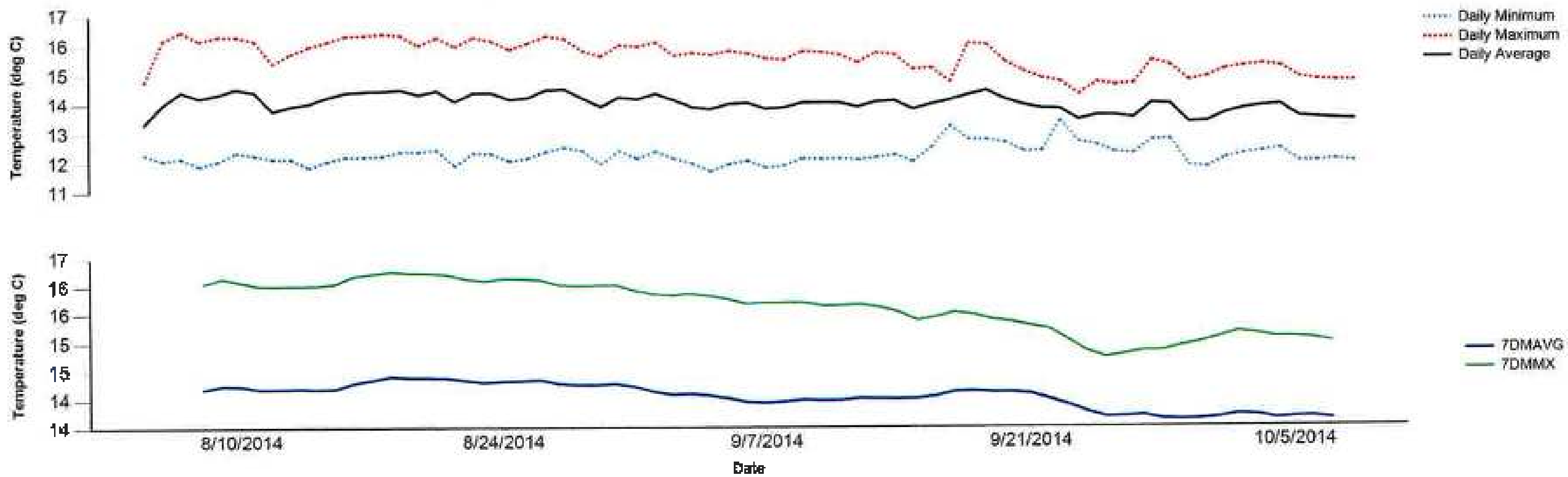


Figure 14: Temperature Profiles for MRSWINGB (2014), Site: 10000872

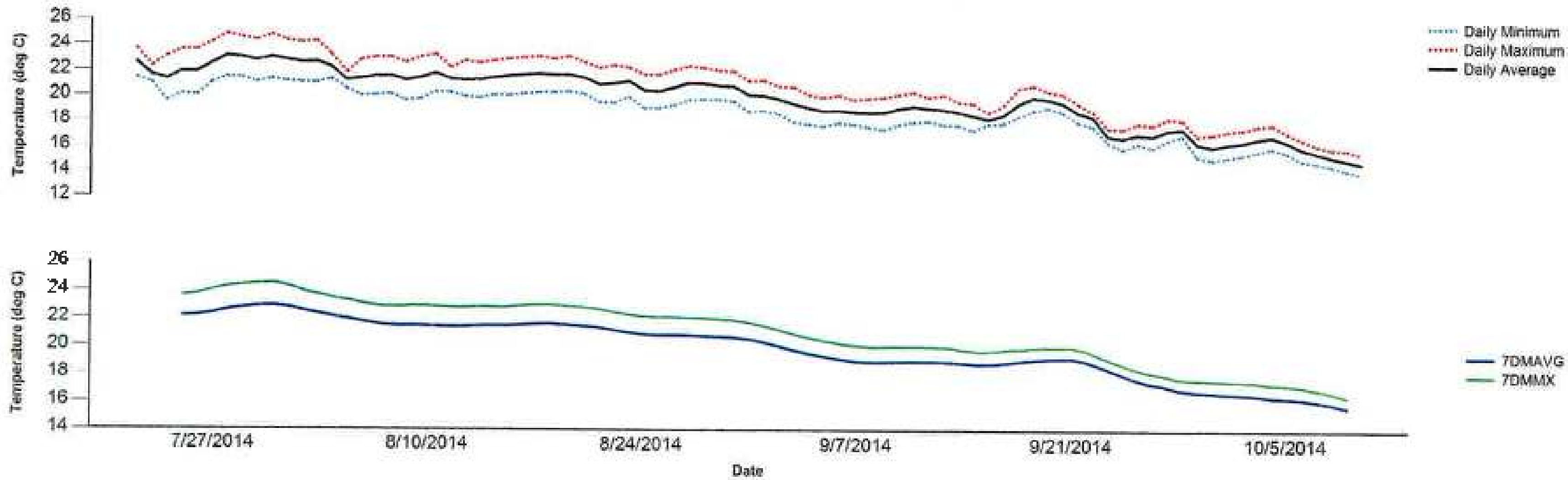
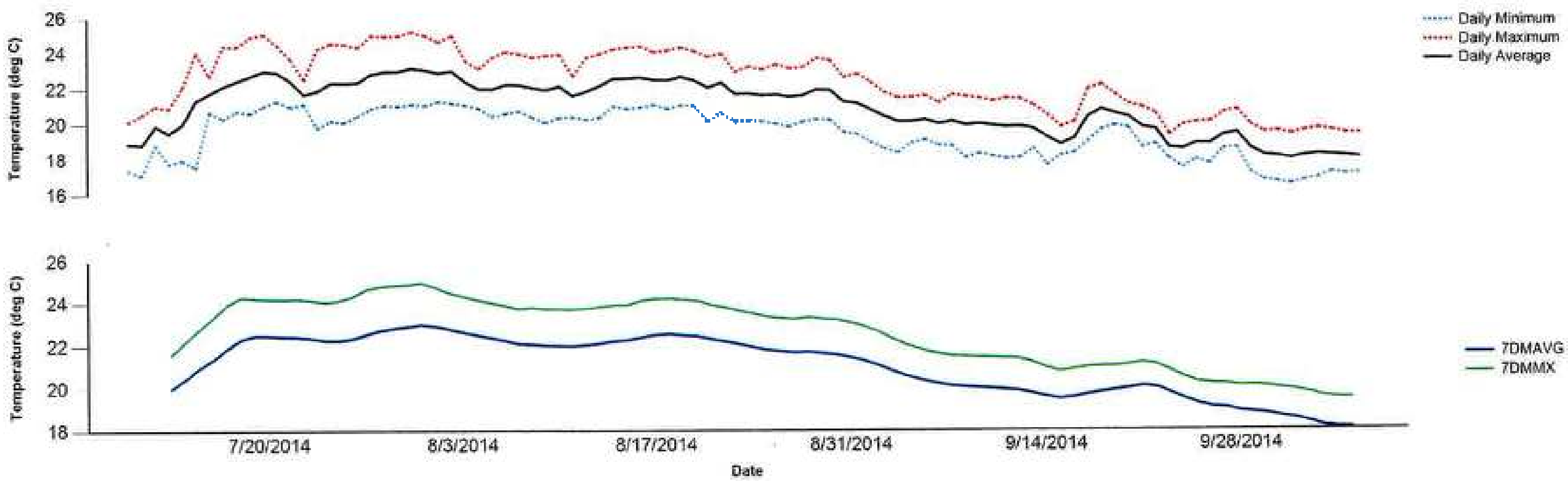


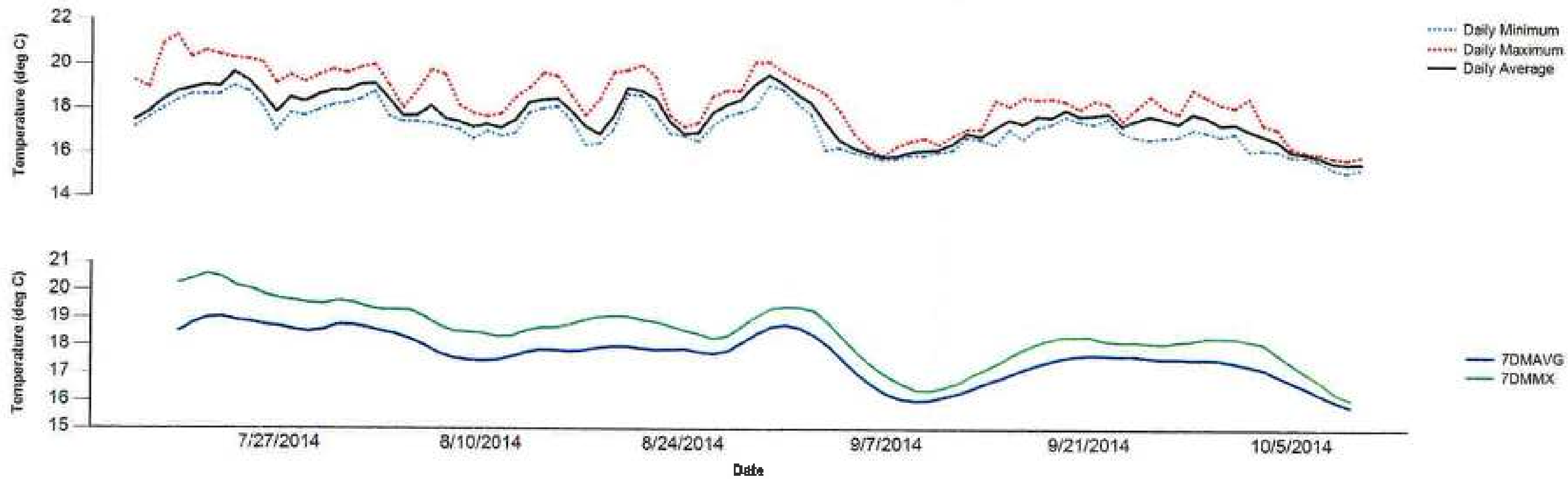
Figure 15: Temperature Profiles for MRVINCENT (2014), Site: 10000673



Temperature Monitoring Summary Report

GREEN DIAMOND RESOURCE COMPANY

Figure 16: Temperature Profiles for RMRBCATR (2014), Site: 10000674



Temperature Monitoring Summary Report

GREEN DIAMOND RESOURCE COMPANY

Figure 17: Temperature Profiles for WARRENCK (2014), Site: 10000675

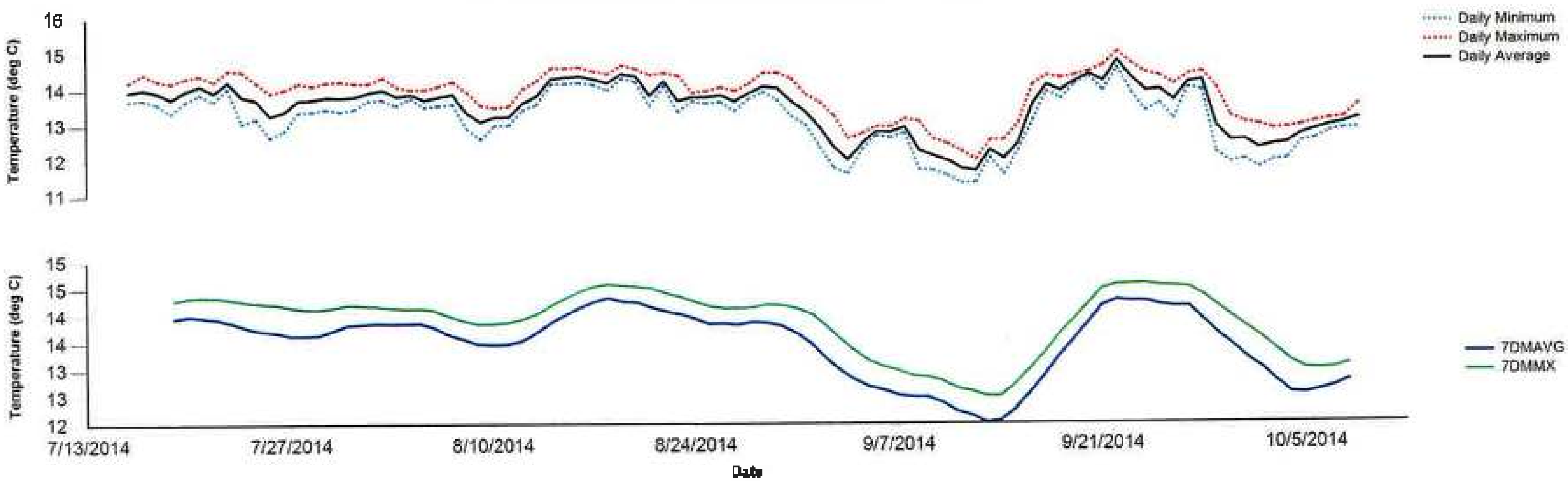
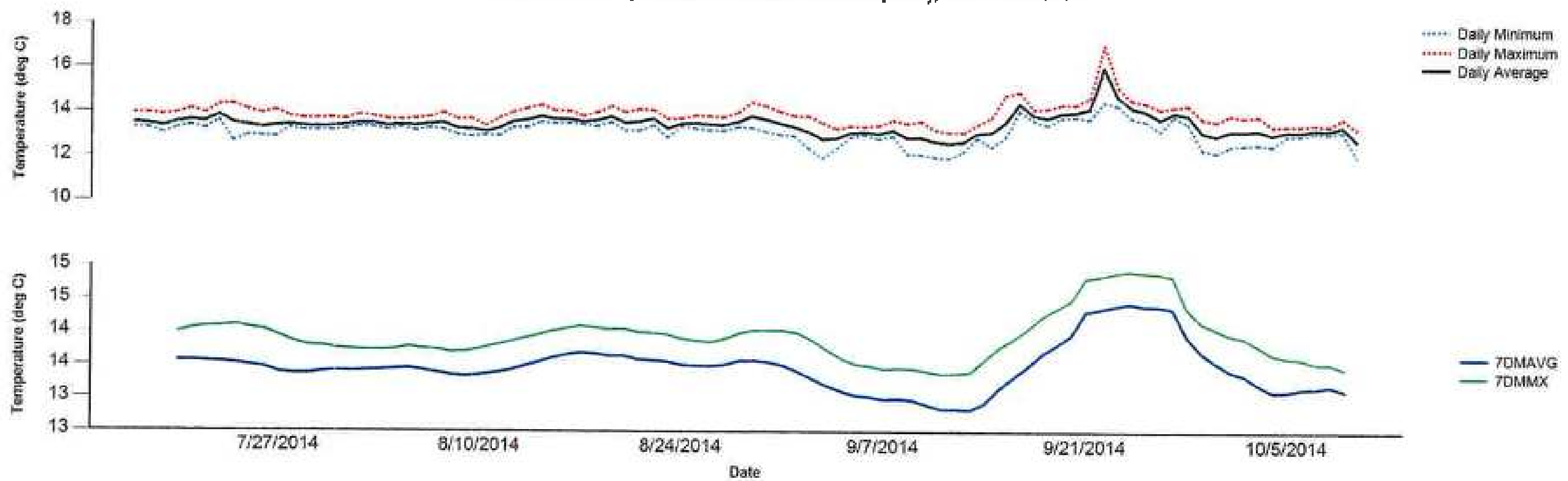


Figure 18: Temperature Profiles for WWCK (2014), Site: 10000676



Conclusions

Evaluation of the maximum temperature recorded during the monitoring period (Tmax) and the Mean Weekly Average Temperature (7DMAVG(A)) reveal that in some areas of the Mad River and tributaries, temperatures are reaching lethal thresholds for salmonids. One salmonid population of particular interest is adult summer run steelhead. Summer steelhead populations are found in mainstems and tributaries of Smith River, Klamath River, Trinity River, Mad River, Eel River, and in Redwood Creek (personal communication Seth Naman NOAA fisheries 2015). Nowhere in California are summer steelhead considered abundant – the runs in many streams consist of less than 100 fish (Barnhart 1986; CDFG unpublished data), and the most recent population assessment for Mad River is 322 adults (2014 Mad river summer Steelhead Dive Report). Summer steelhead enter Mad River in late winter through early spring and must find deep pools with cold water, adequate food, and protection from predators to survive hot summer months until they spawn the following fall or winter.

As pointed out in the introduction, negative impacts of climate change may have a direct impact on threatened summer steelhead populations. Though our data suggest locations along the Mad River approaches lethal thresholds for salmonids, it is important to note cold water inputs from tributaries such as Canon Creek, Lindsay Creek, Warren Creek, and Widow White Creek are providing cold water refugia and water releases from Mathews Dam may assist summer run steelhead by providing a greater quantity and quality of water better suited to assist survival of these fish during low-flow season. The cold water refugia and augmented flows provide a thermal buffer, which may be the difference between the survival or loss of summer steelhead in Mad River. Other factors that influence temperatures in Mad River and its tributaries include: ambient air temperature, percent canopy cover, hyporheic inflow, other cold water tributary/spring inflow, and gravel seeps.

The effectiveness of the MRCTMS is based on inherit design limitations include: sampling period, sampling locations and access, (no) budget, lack of dedicated equipment (HOBOs), reliance on volunteer labor, and Mad River being a low priority for state and federal monitoring efforts and funding all present a challenge to the continuation of the CTMS as a long-term study. To continue the MRCTMS, more partnerships and funding sources will need to be identified and sourced to support this effort.

Acknowledgements

The current ability of the MRCTMS to be successfully implemented is dependent on volunteers and partnerships. Every aspect of this project, from the creation of the study, building of HOBO housings, deployment and retrieval of the loggers, calibration and data handling, and reporting have been done because of dedicated volunteers and partner staff time. For this reason, a big thanks goes out to:
Jacob Pounds, Dave Feral, Matt House and GDRC crew, Karen Kenfield, Leslie Wolff, Michelle Gilroy, Carolyn Cook, Mad River YCC crew, Hollie Hall, and Steven Lazar. You have helped make this project a success!

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Appendix

Continuous Temperature Monitoring Study for Key Locations on Mad River

MAD RIVER ALLIANCE

Sampling Plan and Quality Assurance Project Plan

GREEN DIAMOND RESOURCE COMPANY

THE GREAT TRIBAL SEAL OF THE BLUE LAKE RANCHERIA

A project of Mad River Alliance, with assistance and cooperation by Green Diamond Resource Company and Blue Lake Rancheria

04.10.14

I. Table of Contents

II. Distribution List

Dave Feral, Mad River Alliance

Matt House, Green Diamond Resource Company

Michelle Fuller, Blue Lake Rancheria Environmental Programs Department

Jacob Pounds, Blue Lake Rancheria Environmental Programs Department

1. Introduction

This Sampling Plan (SP) and Quality Assurance Project Plan (QAPP) is intended to offer clear instruction and guide all activities and efforts to collect continuous temperature monitoring data on Mad River during low-flow, warm weather periods. The purpose of this study is to create a data set to determine mainstem and tributary temperatures in key locations throughout the Mad River Watershed; to gather and process data in such a way that it is representative and repeatable and ensure data is of sound quality.

This document consists of 3 parts:

- The Sampling Plan, which outlines and describes equipment, sampling timing, locations, and methods.
- A Quality Assurance Project Plan, which outlines and describes equipment calibration, data collection and analysis, and Quality Assurance/Quality Control methods (QA/QC)
- A Memorandum of Understanding (MOU) between Green Diamond Resource Company (GDRC) and Mad River Alliance (MRA) regarding the equipment loan.

Additionally, documents related to equipment or any other information necessary to ensure this project functions properly will be attached in an appendix.

2. Background

The Environmental Protection Agency (EPA) listed Mad River as impaired for temperature in 2005 on the Clean Water Act (CWA) Section 303d list. A temperature Total Maximum Daily Load (TMDL) does not yet exist for Mad River. Mad River was first listed on the 303d list in 1992 for sediment/siltation/turbidity, and in 2007 the TMDL was released for that particular listing.

Very little monitoring has been done to record ambient stream temperature continuously in Mad River, and therefore, this project should help fill in existing data gaps and further understanding of how Mad River is functioning. The Humboldt Bay Municipal Water District (HBMWD), the owner and operator of Matthews Dam and the party responsible for delivery of bulk water to industry and municipalities in the Humboldt Bay area is interested in how flow releases from the dam affects water quality in the lower Mad River. Little is known about how dam releases affect the quality and quantity of water in lower Mad River and this study will help to fill in data gaps to aid in making informed decisions about water releases.

Stream temperature is a critical component of overall watershed health in Mad River, especially because Mad River supports multiple runs of anadromous fish. These species include pacific lamprey, summer and fall/winter steelhead, fall/winter Chinook salmon, and fall/winter coho salmon. Historically, eulachon and green sturgeon were also reported to inhabit Mad River.

These fish species have a mortality threshold of about 73 degrees Fahrenheit, or approximately 23 degrees Celsius. Because of this, cool overall stream temperatures, cold-water tributary confluence refugia, and hyporheic connections where ground-surface water seeps emerge from substrate are critical habitats. These habitats are especially crucial during the hotter, low-flow periods of the year, typically June-October, and this study is designed to operate during that time frame.

3. Project/Task Description

This Continuous Temperature Monitoring Study (CTMS) will be implemented by GDRC staff, MRA staff and BLR staff. Having a clear description of the responsibilities and roles of all parties, as well as defining and documenting the implementation is crucial.

GDRC staff is responsible for:

- Providing the HOBO temperature (HOBOs) loggers to record data
- Calibrating the HOBOs as per the manufacturer's instruction

- Downloading, processing, and analyzing the data in a manner consistent with GDRC's QAPP and making the data available to MRA

Because GRDC is operating under their own approved QAPP, details pertaining to their responsibilities will be referenced only and not included in this QAPP.

MRA Staff or Volunteers are responsible for:

- Creating and maintaining this Sampling Plan and QAPP
- Picking up the HOBOs from GDRC after they have been calibrated
- Deploying the HOBOs in accordance with this Sampling Plan (SP).
- Retrieving the HOBOs in accordance with this SP.
- Returning the HOBOs to GDRC within one week of retrieval, in a condition as close to when they were loaned out as possible.
- Documenting the deployment/retrieval effort to create an adaptive management plan for future deployment/retrieval events, as necessary.
- Writing a Summary Report (SR)
- Making the data available to the public and interested parties.

BLR Staff are responsible for:

- Assisting MRA staff or volunteers with all of the duties listed above under the 'MRA Staff or Volunteers are responsible for:' heading.
- Technical assistance and capacity building for the CTMS Study.

4. Deployment

At least 2 people are needed to both deploy and retrieve the HOBOs. The same people that deploy the HOBOs should be the same people that retrieve the HOBOs, to ensure efficient and proper recovery of each HOBO. If the same people cannot return to retrieve the HOBOs, due to scheduling conflicts, emergency, illness, etc., then the procedures outlined in this QAPP in regards to deployment and retrieval (logbook, photos, GPS points) should guide substitute people to the sites with reasonable ease and efficiency.

Every effort will be made to ensure both deployment and retrieval will be done in one day. If this is not possible, every effort will be made to deploy and retrieve all HOBOs in the fewest number of days possible. This may mean beginning very early in the morning and working throughout the entire day(s) of deployment/retrieval.

The target window for deployment will take place June 1 – October 31, and will be adjusted based on water year and flow, taking into consideration annual weather patterns and % of precipitation above or below normal. If a large storm event, one that would bring the flow above 200 cfs at the USGS highway 299 gauge, is predicted to fall within that window, HOBOs will be pulled to prevent loss of equipment and data.

When HOBOs are initially picked up from GDRC, a spreadsheet with the date and time, each individual serial number and condition of HOBO, and person picking up HOBO will be signed by the person at GDRC and person picking up the HOBOs. Upon return, the same sheet will be used to sign in all the HOBOs.

During every deployment, a GPS point and at least two photos will be captured to ensure retrieval of each HOBO. A detailed description of the access and placement location of the HOBO will also be recorded, along with stream features (stream boulders, tributary junctions, or other reference markers).
HOBO deployment points will **NOT** be flagged to discourage theft and vandalism. This makes the information recorded with the logbook, photos, and GPS extremely important and valuable to the retrieval of the HOBOs.
Subsequent deployments will be located in the same location, to ensure consistency and data comparability between years and sites.

5. Retrieval

When retrieving the HOBOs, serial number, site name, date, and time of retrieval will be written on flagging and tied directly to the HOBO unit, to maintain site accuracy. This information will also be recorded in the logbook.

6. Documentation

Documentation is key throughout the process of deployment and retrieval of the HOBOs to ensure proper deployment and retrieval practices are used and data collected is accurate. The process of documentation begins with creating a sampling map with desired monitoring sites. Once the number of HOBOs available to monitor temperature is known, sites will be selected from the map (Appendix A). If the number of HOBOs fluctuates from year-to-year, a core set of sites will be established then a second tier, third, etc. This is to establish long-term datasets for the purpose of this CTMS.

When setting out to deploy or retrieve a HOBO, a dedicated logbook and camera will accompany the person(s) doing the deployment/retrieval. The logbook should always capture this information at every site:

- Site Name
- Date
- Time
- Person/people deploying HOBOs
- Number of HOBOs deployed
  - Serial number of HOBOs
- Site conditions:
  - Habitat type (pool/riffle/run)
  - Water Depth (estimate)
  - Cover (% estimate)
  - Presence/absence of algae (photograph if possible)
  - Presence/absence of fish species (photograph if possible)
  - Evidence of human or animal activity (photograph if possible)
  - Condition of HOBO on deployment/retrieval
  - And any other information that is directly related to this CTMS

Photos will be used to capture key identifying features of sampling sites to aid in the retrieval of the HOBOs, and capture ambient environmental conditions at each site. At least two will be taken at each site. Digital copies of photos will be kept on a computer and flash drive for backup, along with the logbook to ensure safekeeping. The logbook, flash drive, and all associated documentation materials will be kept by MRA.

At the end of each deployment/retrieval cycle, an evaluation of deployment/retrieval procedures will be discussed between appropriate parties to determine whether the deployment/retrieval procedures and documentation is sufficient to create representative, meaningful datasets. If it is determined that the deployment/retrieval or documentation procedures require updates, necessary actions will be taken to update the SP.

7. Data Quality Objectives

The Data Quality Objectives (DQOs) for this CTMS are as follows:

- 100% of the HOBOs are deployed and retrieved successfully, according to the guidelines in the SP.
- All documentation of the deployment and retrieval is noted in the logbook, according to the SP.
- 0% HOBO failure rate.

8. Instrument Testing, Inspection, and Maintenance Requirements

All HOBOs will be inspected and ensured to be of proper working order by GDRC staff according to their QAPP and manufacturer's recommendations before deployment. If HOBOs are found to be not in proper working order, they will not be used for this CTMS.

9. Instrument Calibration and Frequency

All HOBOs will be calibrated to manufacturer's standards, according to the guidelines set by GDRC's QAPP. Calibration will occur before deployment every year. If a HOBO fails calibration or does or cannot calibrate according to GDRC's QAPP, it will not be used for this CTMS.

10. Data Management

GDRC will download, store, analyze, and make available data from the HOBOs used for the purpose of this CTMS. GDRC will handle these data in the same manner they download, store, and analyze data for their own studies, and according to guidelines in their QAPP. GDRC will review, validate, and verify all data from the HOBOs for this CTMS, according to their QAPP. Data reviewed, validated, and verified in this manner will be considered acceptable for analysis.

Data for the CTMS will then be delivered to MRA and written into a report by MRA that will be made publicly available on their website or however they see fit. Requests for the CTMS data will be handled by a MRA representative.

11. Assessments and Response

Following the annual data analysis, an assessment will be made to determine whether or not the DQOs were met. If DQOs are not met, further analysis will be implemented to determine what caused the failure to meet the DQO and an appropriate modification of the SP will be made to ensure DQOs are met.

To determine whether or not DQOs are met, MRA will:

- Review the logbook to see if any complications are noted.
- Compliance or failure to meet DQOs will be noted in the logbook.

Based on the findings of the DQO assessment for each site, an appropriate response and update of the SP will follow. These actions will be recorded and written in a Summary Report (SR) that will catalogue the data collected, success or failure of each site to comply with DQOs and actions taken to achieve DQOs in following sampling periods. This report will be written by a MRA representative, and completed in a reasonable timeframe, but before the sampling period for the following year begins.

Upon completion of this report, data and the report will be made available for the public. To ensure future safety of equipment and sampling sites, exact sites will not be revealed, but referred in the reports in a general manner.

This report will contain:

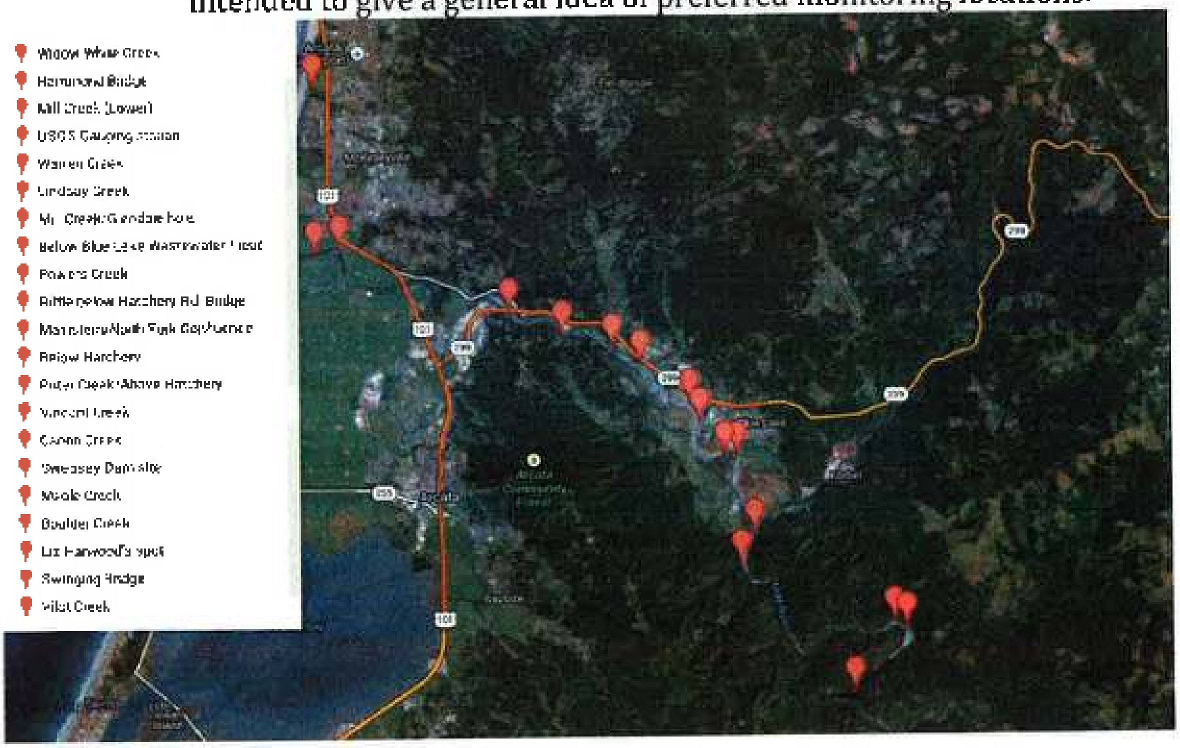
- Number of sites sampled
- Number of sites that met DQOs
- Number of sites that did not meet DQOs
- Summary of continuous monitoring data
- Number of instances where water temperature exceeds basin Water Quality Standards

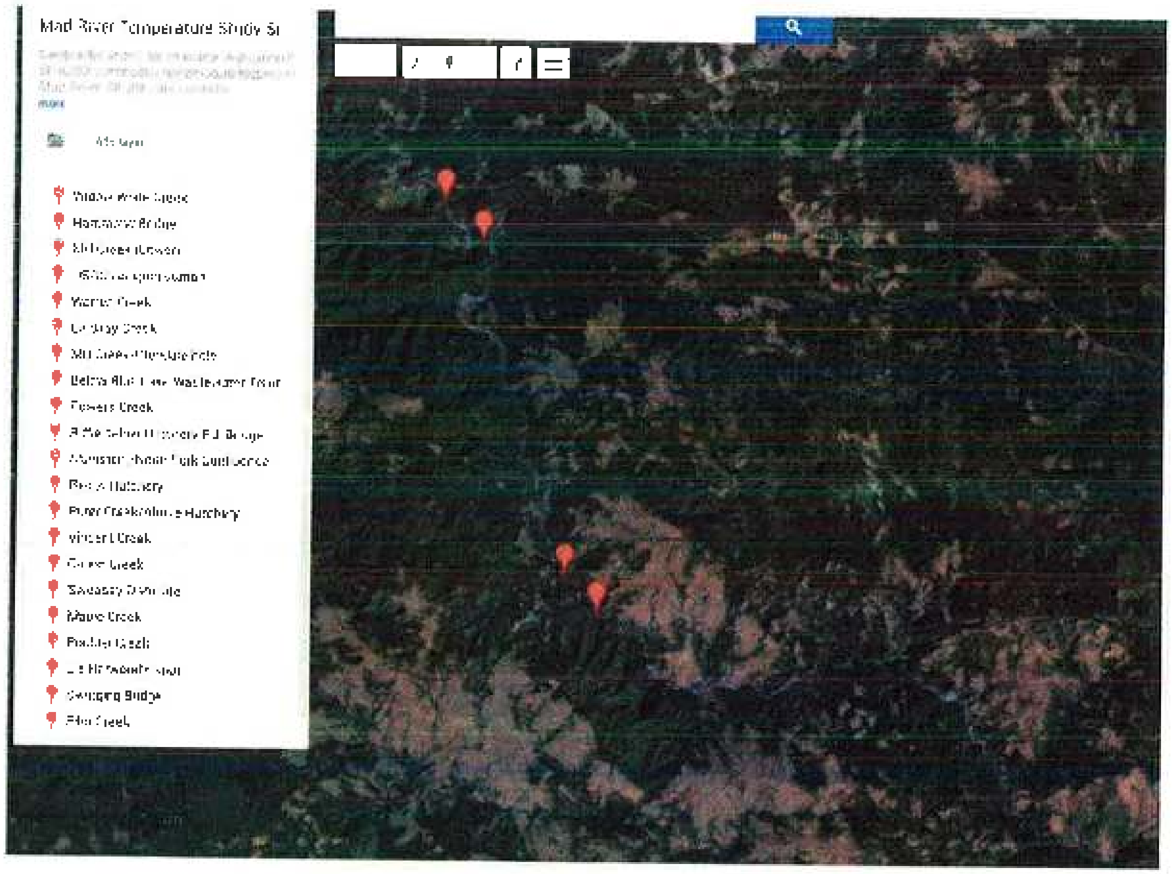
It will be the responsibility of MRA to respond to inquiries for the report and distribute them to interested parties. Additionally, an MRA representative will handle any requests for raw data.

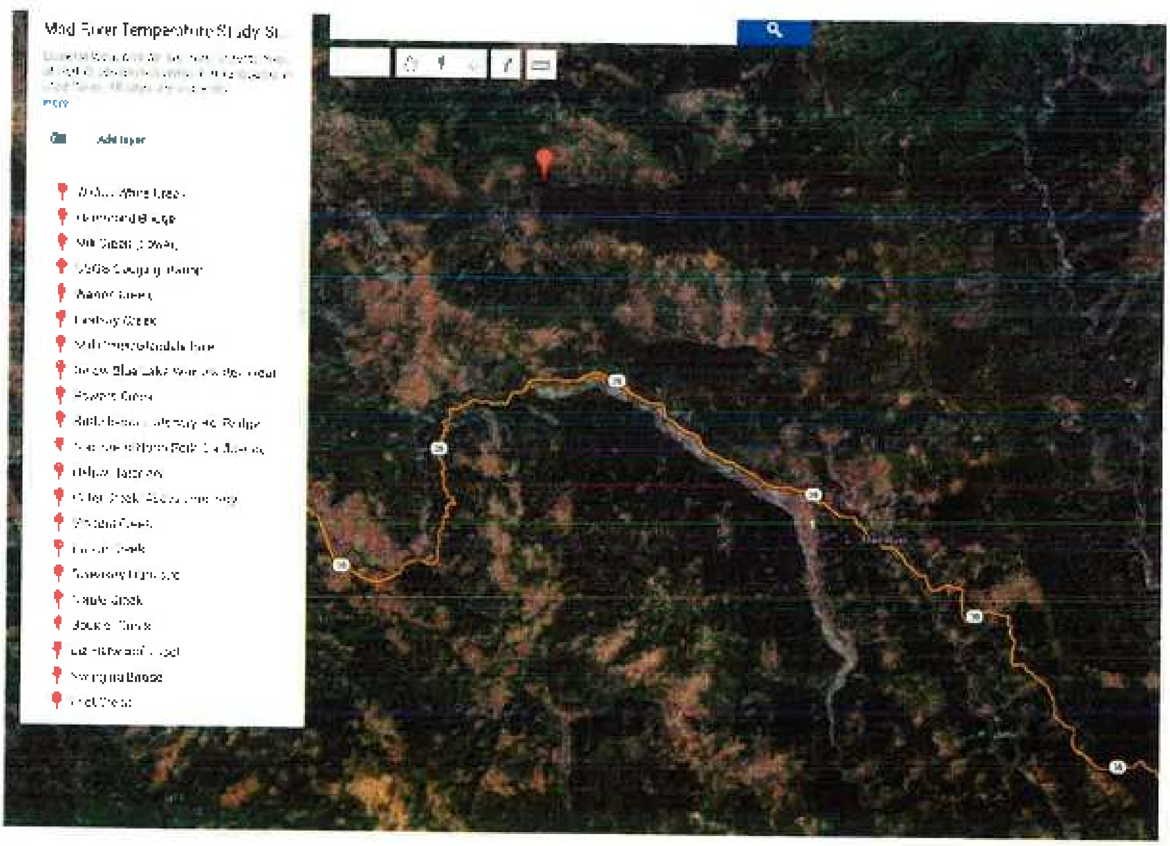
Appendix:

F. Maps and Proposed Sites
G. Manufacturers' Information for HOBO loggers
H. GDRC QAPP for Calibration
I. MOU
J. Sign in/out sheet

A. Maps and proposed sites for the CTMS
   a. Sites will be selected and recorded in 2014, the initial year of the study, and then more accurate maps will be made. These maps are intended to give a general idea of preferred monitoring locations.




Mad River Temperature Study Si


Mad River Temperature Study Si

B. Manufacturers' Information for HOBO loggers

HOBO Water Temperature Pro v2 Data Logger - U22-001

Water Temperature (400 ft.)

Qty	1-9	10-99	100+
$US	$129	$120	$110

Contact Onset at 1-800-564-4377
Measures:
Temperature, Water Temp

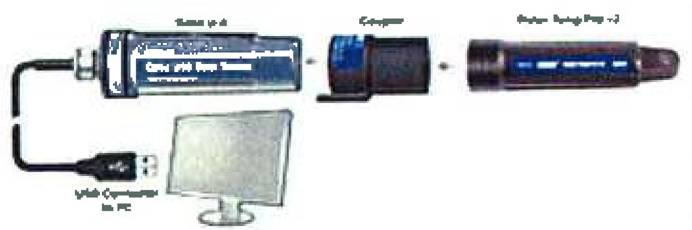
Features:

- Research grade measurements at an affordable price
- Waterproof to 120 meters (400 feet)
- Data readout in less than 30 seconds via fast Optic USB Interface

---

Description:

The HOBO Water Temp Pro v2 is durable with 12-bit resolution. Complete with a precision sensor for ±0.2°C accuracy, this logger measures temperatures between -40°C and 70°C (-40° to 158°F) in air and up to 50°C (122°F) in water. Its waterproof, streamlined case allows for extended deployment in fresh or salt water. Moreover, the Water Temp Pro v2's optical USB interface makes it possible to offload data even while the logger is wet or underwater. A solar radiation shield is required to obtain accurate air temperature measurements in sunlight (RS1 Solar Radiation Shield, assembly required; or M-RSA pre-assembled Solar Radiation Shield).



Optical interface for data transfer - click to zoom

Detailed Specifications:

Operation range[1]: -40Â° to 70Â°C (-40Â° to 158Â°F) in air; maximum sustained temperature of 50Â°C (122Â°F) in water
Accuracy: Â±0.21Â°C from 0Â° to 50Â°C (Â±0.38Â°F from 32Â° to 122Â°F)

Resolution: 0.02Â°C at 25Â°C (0.04Â°F at 77Â°F)

Response time: (90%) 5 minutes in water; 12 minutes in air moving 2 m/sec (typical)

Stability (drift): 0.1Â°C (0.18Â°F) per year
Logger
Real-time clock: Â± 1 minute per month 0Â° to 50Â°C (32Â° to 122Â°F)

Battery: 2/3 AA, 3.6 Volt lithium, factory-replaceable ONLY

Battery life (typical use): 6 years with 1 minute or greater logging interval

Memory (non-volatile): 64K bytes memory (approx. 42,000 12-bit temperature measurements)

Weight: 42 g (1.5 oz)

Dimensions: 3.0 cm (1.19 in.) maximum diameter, 11.4 cm (4.5 in.) length; mounting hole 6.3 mm (0.25 inches) diameter

Wetted materials: Polypropylene case, EPDMÂ® o-rings, stainless steel retaining ring

Buoyancy (fresh water): +13 g (0.5 oz.) in fresh water at 25Â°C (77Â°F); +17 g (0.6 oz.) with optional boot

Waterproof: To 120 m (400 ft.)

Shock/drop: 1.5 m (5 ft.) drop at 0Â°C to 70Â°C (32Â°F to 158Â°F)

Logging interval: Fixed-rate or multiple logging intervals, with up to 8 user-defined logging intervals and durations; logging intervals from 1 second to 18 hours. Refer to HOBOware software manual.

Launch modes: Immediate start and delayed start

Offload modes: Offload while logging; stop and offload

Battery indication: Battery voltage can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.

NIST certificate Available for additional charge

The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

IMPORTANT: The plastic case will become brittle at temperatures lower than -20Â°C. If the logger is deployed in a location where the temperature drops below -20Â°C, make sure the logger remains stationary and is not pulled on or struck. Return the logger to above -20Â°C before handling.

C. GDRC QAPP

Green Diamond Resource Co

Property-wide Water Temperature Monitoring

June 2014

Background and Objectives

Stream water temperature monitoring on Green Diamond Timberlands began in 1994 and is ongoing today. As part of Rapid Response Monitoring, water temperature will be monitored on an annual basis within both Class I and II watercourses throughout the Plan Area.

The following objectives have been developed for water temperature monitoring:

- Document the highest

    a) 7DMAVG (highest 7-day moving average of all recorded temperatures),

    b) 7DMMX (highest 7-day moving average of the maximum daily temperatures); this statistic is synonymous with Maximum Weekly Maximum Temperature (MWMT, Welsh et al., 2001).

    c) Seasonal temperature fluctuations for each site for both Class I and Class II watercourses.

- Identify stream reaches with temperatures that have the potential to exceed the monitoring thresholds relative to the drainage area above the monitoring site for both Class I and Class II watercourses.

Class I and II Watercourse Monitoring Methods

Equipment Specifications and Replacement

Water temperature data is collected using HOBO® Water Temperature Pro v2 data loggers (U22-001, Onset Computer Corporation, Bourne, MA). This data logger has an operational range in water (-40 °C to 50 °C) and accuracy (± 0.21 ºC at 0 °C to +50 °C) that is suitable for satisfying the objectives of this monitoring project. The battery in this data logger is not replaceable and has a life expectancy of six years. Additional details on specifications for this equipment can be found on the manufacturer's website.

Data loggers used for this monitoring program will not be more than six years old to avoid battery failure during any deployment and data loggers will be retired once they exceed their life expectancy. Prior to 2010 comparable data loggers (e.g., TidbiT and HOBO Water Temperature Pro) produced by the same manufacture were used to measure water temperature for this project. Replacement data loggers may differ from the current model to keep up with technological advances in monitoring equipment.

Equipment Calibration

The annual calibration of all recorders (i.e., data loggers) is necessary to ensure that all deployed recorders operate within the manufacturer's specifications during each monitoring period and that batteries are in good condition. The calibration process is not an attempt at documenting precision beyond that of the manufacturer's specifications or an attempt at establishing correction factors to be applied to the data after retrieval. Any recorder that fails calibration will be calibrated again before it is returned to the manufacture for repair or replacement.
At the beginning of each field-monitoring season every data logger scheduled for deployment is calibrated, in an ice bath using the procedure described below.

1. Make an ice bath using an ice chest (size ≈ 70 quart) filled approximately half way with crushed ice and water to produce a slurry.

2. Using a NIST certified thermometer, verify that the water temperature is at or slightly less than 0 °C. The water temperature will vary slightly from 0 °C depending on the purity of the water.

3. Launch data loggers with a logging interval of 30 seconds. Only calibrate a maximum of 60 loggers at any one time.

4. Place launched recorders into the ice bath ensuring that the sensor is fully submerged on each data logger.

5. Allow data loggers to collect data in ice bath for at least three hours allowing time for acclimation of both the recorders and the water. Periodically record the bath temperature using the certified thermometer during this time. Do not move or disturb the ice bath during this time period.

6. Remove all ice from the ice bath, leaving only the recorders and the remaining water. Place the cooler at room temperature to allow the water to gradually warm to the ambient temperature. Periodically record the bath temperature using the certified thermometer.

7. Remove and download water temperature data from all data loggers.

8. Review the thermograph for each data logger and verify that the data are consistent with the expected water temperature values recorded during the deployment. Details for the verification process are below.

Each data logger is calibrated to ensure that it consistently and accurately recorded the expected water temperature (i.e., temperature measured by the certified thermometer) while in the ice bath and during the warming period. Data logger temperature measurements must be within the specified accuracy for the equipment used (e.g., ± 0.21 ºC) when compared to the expected temperatures. During the warming period, consistent warming is also assessed. Temperature increases greater than 0.2°C between measurements suggests a problem with the data logger and it must be recalibrated before deployment.