Secchi Monitoring Program

Water Quality Department

The following describes the Grand Lake Secchi Monitoring Program. This program is in cooperation with the Grand County Water Information Network (GCWIN). The objective of this program is to provide a baseline of data to support the Grand Lake Adaptive Management process which supports the Grand Lake clarity standard by:

- Monitoring spatial and seasonal variations in clarity in Grand Lake
- Monitoring spatial and seasonal variations in clarity in Shadow Mountain Reservoir in relation to clarity in Grand Lake
- Monitoring the impacts of the Colorado-Big Thompson (C-BT) Project operations on clarity in Grand Lake and Shadow Mountain Reservoir

This program began in 2008 and is funded by Northern Water and the U.S. Bureau of Reclamation (Reclamation). GCWIN conducts sample collection for the Secchi program.

MONITORING LOCATIONS

The Secchi monitoring program includes seven sampling sites: three sites in Grand Lake and four sites in Shadow Mountain Reservoir.

Table 1. Secchi Monitoring Locations

Station	Description	Latitude	Longitude
GL-WES	Grand Lake south of Shadow Mountain Connecting Channel	40.2419	-105.8215
GL-MID	Grand Lake at mid-section	40.2434	-105.8138
GL-ATW	Grand Lake at Adams Tunnel West Portal	40.2411	-105.8050
SM-NOR2	Shadow Mountain Reservoir at the north end	40.2445	-105.8393
SM-MID	Shadow Mountain Reservoir at mid-section	40.2236	-105.8373
SM-DAM	Shadow Mountain Reservoir at the dam	40.2086	-105.8431
SM-NW1	Shadow Mountain Reservoir northwest of the center	40.2370	-105.8418

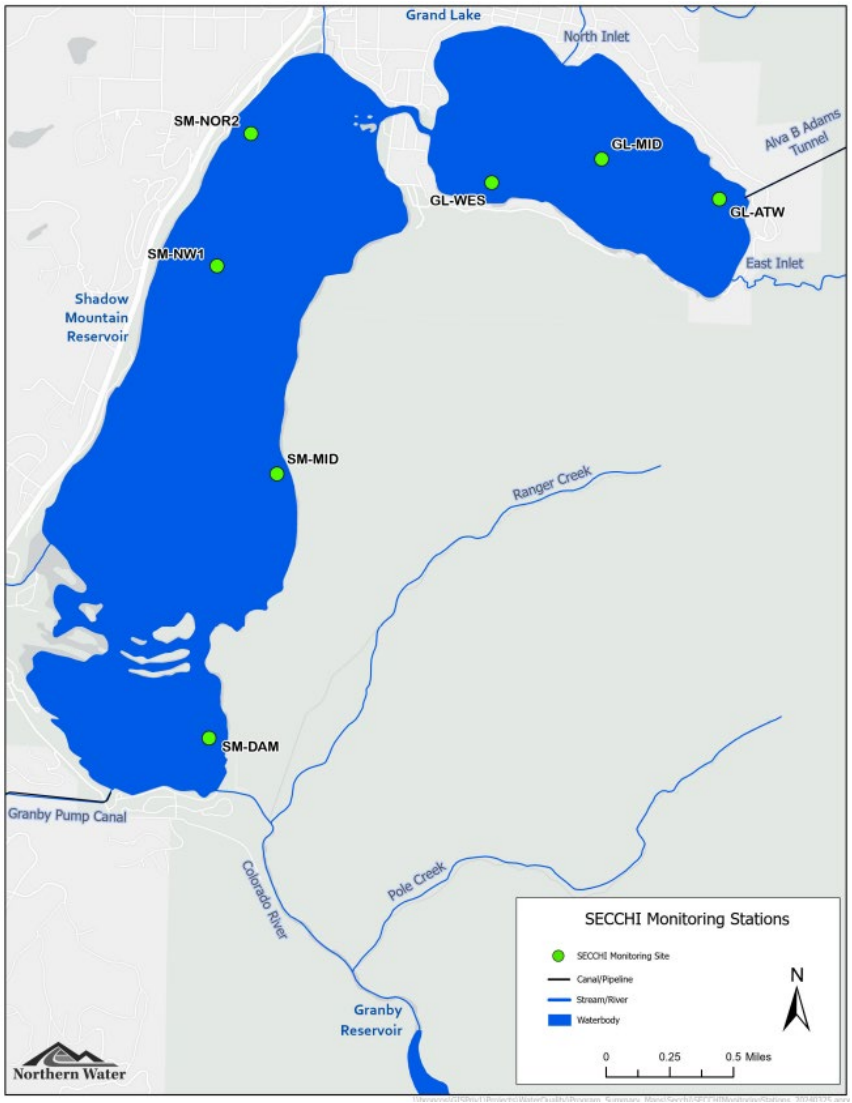

Figure 1. Map of Monitoring Locations

MONITORING SCHEDULE

The monitoring schedule is as follows:

- Monitoring occurs from May/June (after ice is off) – mid-October (as conditions allow), or for a maximum of 24 weeks.
- Secchi measurements are collected three times a week on Monday, Wednesday, and Friday. If a sampling day falls on a holiday, sampling will take place on an alternate day of the week.
- If necessary, based on operational plans during July 1- Sept. 11, Secchi monitoring may be increased to daily measurements (Monday-Friday).
- One day per week Secchi photographs are taken at SM-DAM, SM-MID, GL-WES, and GL-MID.
- One day per week lake profile data are collected at GL-MID utilizing GCWIN's YSI EXO Sonde.
- One day per week a chlorophyll *a* samples are be collected at GL-MID and SM-MID.
- One day per week a phytoplankton samples are be collected at GL-MID and SM-MID.

Secchi measurements are taken by GCWIN's field technicians and adhere to the guidelines set forth in Appendix 2 – Secchi Monitoring Protocol.

DATA MANAGEMENT

GCWIN conducts Quality Assurance and Quality Control (QAQC) on the data recorded on the field sheets and transcribes these data to an Excel file. The Excel files are provided to Northern Water after each sampling event where additional QAQC is done. At a minimum, the data is delivered on a weekly basis. These data are recorded in Northern Water's database as 'Provisional'.

At the end of the Secchi monitoring season, Northern Water works with GCWIN to finalize the data records. The final data are available on Northern Water's website data portal: Water Quality Data or in GCWIN's Database.

SUPPLEMENTAL DATA COLLECTION

In addition to taking Secchi measurements, GCWIN collects profile data, phytoplankton, and chlorophyll samples one time a week in Grand Lake at the GL-MID site.

The lake profile data includes dissolved oxygen, pH, specific conductivity, temperature, and turbidity, chlorophyll a RFU and phycocyanin RFU collected with a YSI EXO3 Sonde. Measurements are taken at one meter increments until a depth of 20 meters, then the increment increases to every 5 meters up to a depth of 60 meters. A standard field sheet is filled out for each lake profile taken.

Chlorophyll samples are also collected one time a week in Shadow Mountain Reservoir and Grand Lake at the SM-MID and GL-MID sites. The chlorophyll samples are collected using a pool hose sampler to collect a composite sample of the water column from 0-5 meters. The samples are filtered and prepared for laboratory analysis by GCWIN. The samples are placed in a cooler with dry ice and shipped to Northern Water for analysis.

Secchi photographs are taken once a week in Grand Lake at GL-WES and GL-MID as well as in Shadow Mountain at SM-DAM and SM-MID. Protocol for Secchi photograph collection is attached in Appendix 3: Field Protocol for Photographs to Accompany Secchi Measurements in Grand Lake and Shadow Mountain Reservoir.

APPENDIX 1 – HISTORY OF PROGRAM CHANGES

Changes to Sampling Schedule, Monitoring Frequency and Sample Collection

Year	Description of Change
2008	Program begins, funded by Northern Water and Reclamation. GCWIN manages and conducts sample collection.
2014	Marks the end of the Volunteer Secchi Monitoring Program, which started in 2008. This resulted in the in discontinuation of some sites and reduced frequency of sampling at other sites that were formerly supported by the volunteer program.
2015	SOP "GCWIN Secchi Manual" is revised and includes QAQC Protocols and sets guidelines for the Secchi Monitoring program.
2016	The program switches from 18 sampling sites to 7 sampling sites as these sites are found to be representative of the larger sampling suite. These sites became the agreed-upon sites that support the Grand Lake Adaptive Management Process.
2017	Secchi measurements shift from being taken Monday, Wednesday, Friday only from July 1-Sept. 11 and once a week during the rest of the season to being taken three times a week from May (ice off) through Oct. 31.
2017	Secchi monitoring began to follow guidelines set forth in the SOP "Secchi Monitoring Protocol for Grand Lake". The manual includes QAQC protocols.
2018	Chlorophyll a samples are added, collected once a week at GL-MID and SM-DAM. These are composite samples collected by sampling the water column from 0-5 meters.
2020	Beginning in 2020 all chlorophyll a samples are analyzed by Northern Water.
2021	Beginning in 2021 profile data were not collected because the GCWIN sonde was out of commission
2021	GCWIN began collecting the weekly chlorophyll a samples instead of Northern Water for logistical reasons
2022	Phytoplankton samples are added on a weekly basis at GL-MID and SM-MID
2024	Profile data collected again with the acquisition of a new sonde for GCWIN

APPENDIX 2 – SECCHI MONITORING PROTOCOL

The objective of this program is to record clarity data in Grand Lake to document short and long-term changes in clarity resulting from natural conditions and from the operation of the C-BT Project. The monitoring program was designed to capture:

- Seasonal variations in clarity in Grand Lake;
- Clarity impacts of C-BT operations in Grand Lake.

Safety

Before launching the boat, the technician must verify that all required safety equipment is on board. Boating safety is crucial, as technicians will be moving around the boat, leaning over the edge and working with equipment.

Technicians should always have access to a life preserver and be educated about safe boating laws and waterway rules. See Colorado's current boating safety recommendations.

At a minimum, ensure the following equipment is on the sampling boat:

- Personal flotation device for each person, Coast Guard-approved, readily available and properly sized for each occupant.
- First aid kit
- GPS
- Extra boat oil
- Equipment required by State and local boating laws, such as fire extinguishers and sound-producing devices.

Monitoring Protocol

All Secchi disk measurements are taken without a view scope first and then with a view scope to maintain consistency with historic data. Measurements are taken without sunglasses and always taken from the shady side of the boat. The technician lowers the Secchi disk through the water column, observing it first without the view scope, then repeating the process with the view scope. All measurements should be conducted by trained personnel. Detailed Secchi depth measurement procedures are provided later in this section.

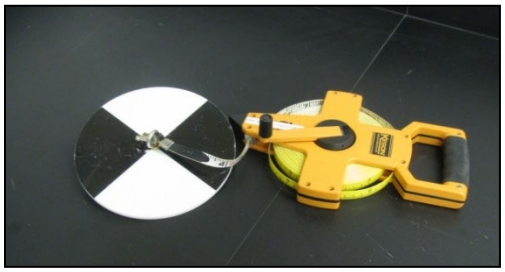

Figure 2 – Secchi Disk with Measuring Reel

Figure 3 - Measuring Secchi depth with a view scope

Monitoring Equipment

- Secchi disc (8" black & white quadrant disk) with weight attached (Figure 2)
- Thermometer
- Calibrated line (fiberglass measuring tape with tenths of feet on one side)
- View-scope (Figure 3) with specifications: 26-inch length, 4.2- inch diameter, neoprene sleeve up 3.5 inches from bottom of scope, matte black interior, plastic lens at bottom, neoprene viewing mask, and handle.
- Field Data Sheets, pencils or permanent markers, clipboard/notebook
- GPS

GPS Instructions for Garmin GPS Map etrex 30x

1. Press and hold the "Power"/"Light" button on the side of the device to turn it on.
2. Using the joystick on the front of the device (directly to the right of the etrex 30x markings) toggle/scroll to the right to the "Where To?" icon. Press down on the joystick to select the icon.
3. The device will move to a new "page". Toggle to the right to the "Waypoints" icon. Select the icon by pressing down on the joystick.
4. Scroll up or down using the joystick to find the site location desired. Select the site by pressing down on the joystick.
5. A new screen with a map will appear. Press down on the joystick again to select the "GO" icon.
6. A new navigational screen will appear to direct towards the desired location. This screen will move as the user travels.
7. On the right side of the device, press the "Back" button. Toggle left, and then down to the "Compass" icon and select the "Compass" icon by pressing down on the joystick.
8. This compass will help direct the user with more accurate location service.
9. To return to the main screen at any time, it the "Back" button on the right side of the device or hit the "Menu" button on the left side of the device.
10. To turn the device off, press and hold the "Power"/"Light" button on the right side of the device.

11. GPS User Accuracy: The GPS locations are set up in Degrees/Minutes/Seconds notation. A second of either latitude or longitude translates to about 100 feet. We ask that you try to be between +/- 0.5 seconds of latitude and longitude when finding your site.
12. Note: These instructions are model-specific and may have to be revised if a different model is used

Maintenance

Before going out, ensure the fiberglass tape and bolt to the Secchi disk are not damaged/loose.

General Protocol

1. Measurements should be taken between 10:00 a.m. and 2:00 p.m.; however, adverse weather conditions are always more likely in the late mornings and early afternoons. Therefore, to avoid any issues with data collection from weather related conditions, like harsh winds, GCWIN field staff will begin collection earlier in the morning, but never earlier than 8:00 am.
2. Approach the sampling site slowly. Approach the sampling site slowly, making gentle turns, and gradually stopping the motor to minimize water disturbance to ensure quality sampling.
3. Use the GPS to ensure you are at the correct location. All the locations are stored in the GPS units. Choose your location, and motor towards it. The GPS will beep when you are approaching the location, and then again when you are at the location, which appears to be within 50 feet accuracy.
4. Before taking measurements, fill out field sheet information for site number and name, sampler's name, GPS coordinates, and Date/Time.
5. Fill out the **Description** Section (except for water color), being sure to circle one answer in each column.
    a. **Recreation Potential**
    b. **Physical Appearance**
    c. **Comments\Water Quality Narrative:** Add a narrative description to give context to your ratings, and to document any abnormal or remarkable conditions. Examples might include excessive pine pollen or needles, sediment coming from adjacent rivers, exceedingly calm conditions, etc.
6. Fill out the **Weather** Section, being sure to circle one answer in each column.
7. **Sky** – Make your best estimate for cloud cover using the descriptions.
8. **Wind** – Make your best estimate using the descriptions.
9. Measurements are made in the shade of the boat, with the sun to your back.
10. Do NOT wear tinted or polarized sunglasses to take measurements.
11. Take Secchi measurements first **without** the view scope and record the measurements on field data sheet (see "measurement procedure" below). Repeat the same procedure **with** the view scope. **NOTE:** When using the view scope, submerge the view scope just below the surface, no more than necessary to eliminate air bubbles. The technician will also place the view scope in the water trying to keep the plastic lens as close to the water surface as possible to eliminate shortening the measurement.
12. **Water Color** – using the color chart, lower the Secchi Disc to half of the average Secchi depth, and compare the water color to the chart. Choose only one color.
13. If the wind is causing the boat to drift, the Secchi tape may not be perpendicular to the water surface and could give a biased reading. Make a note in the Field Sheet if that is the case. (Tape Bend)

Measurement Procedure

1. **Lowering Depth:** The technician will slowly lower the Secchi disk through the water column on the shady side of the boat and carefully watch the disk until it just disappears.
2. Read off the tape measure where it meets the surface of the water and record the lowering depth on field sheet.
3. The depth is measured from the water surface; if there are small fluctuations in the water surface take the average of the depths.
4. **Raising Depth:** From this point the Secchi disk will be lowered two additional feet from first reading.
5. The technician will once again begin to raise the Secchi disk until it becomes visible again.
6. Read off the tape measure where it meets the surface of the water and record the raising depth on field sheet.
7. The depth is measured from the water surface; if there are small fluctuations in the water surface take the average of the depths.
8. **Offset** should be added for the final Secchi depth value. The offset is the distance measured with the tape between the zero mark and the Secchi Disk. (Offset may or may not apply depending on the type of Secchi disk being used.)
9. **Repeat steps 1-3 using the view scope.**
10. If the Secchi disk hits bottom or is stopped by weeds **discontinue measurements at the site** due to risk of sediment stirring, and record the depth that you hit bottom. In the comments section write which statement corresponds to your reading:
11. "Hit bottom prior to Secchi lower, depth greater than >_____."
12. "Hit bottom prior to Secchi raise. No raise reading taken."
13. A measurement may be repeated if there are interferences that affect the initial measurement (i.e. wave action, boat traffic, wind gusts, etc…). In these instances, multiple measurements may be reported with a comment explaining why replicate measurements were taken.
14. If the tape cannot be kept perpendicular to the water, then the measurement should be flagged and entered as "less than" the measured value. Such measurements may be discarded for use in assessment of the clarity goals.
15. Two measurements will be made independently by each sampler: the reader and the data recorder will switch roles and repeat steps 1-4.
16. Both measurements should be entered in the field sheet with appropriate comments, for example:
17. "Floating vegetative debris (pollen, twigs, pine needles)"
18. "Floating and submerged aquatic weeds"
19. "Decreased visibility due to higher amounts of suspended solids"

Field Sheet for Secchi Measurements

Date: _____
Field Tech Name #1: _____
Field Tech Name #2: _____

					NO SCOPE		SCOPE							
Site #	Station Name	X - Longitude	Y - Latitude	Time	Lower	Raise	Lower	Raise	Water Temp	Water Color	Rec Pot.	Phys App.	Sky	Wind
1	SMR-DAM	105° 50' 34.98" W	40°12' 31.12" N	#1:										
				#2:										
2	SMR-MID	105° 50' 15.10" W	40°13' 26.40" N	#1:										
				#2:										
3	SM-NW1	105° 50' 30.55" W	40°14' 13.31" N	#1:										
				#2:										
4	SMR-NOR2	105° 50' 22.4" W	40° 14' 40.5" N	#1:										
				#2:										
5	GL-West	105° 49' 17.27" W	40° 14' 30.92" N	#1:										
				#2:										
6	GL-ATW	105° 48' 18.14" W	40° 14' 27.84" N	#1:										
				#2:										
7	GL-MID	105° 48' 49.64" W	40° 14' 36.37" N	#1:										
				#2:										

Notes: Secchi sites must be done in the same order every time. One sample taken at a time. Neat and legible handwriting please.

Comments:

Site #1 _____

Site #2 _____

Site #3 _____

Site #4 _____

Site #5 _____

Site #6 _____

Site #7 _____

Field Sheet with Descriptions

Station ID:_____
Date/Time: _____
Surface Water Temperature (deg F)**:** _____

Secchi Disc Transparency (record to nearest 1/10th of a foot)**:**
(Remember to remove sunglasses and to use only non-tinted prescription glasses)

Sampler	View Scope		Tape perpendicular to water surface?		Average Depth	Offset	Lowering Depth (no offset)	Lowering Depth (offset added)	Raising Depth (no offset)	Raising Depth (offset added)
	Yes	No	Yes	No						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						

Did you hit bottom? Yes ☐ No ☐ If Yes, depth at bottom (ft.):_____

Description (circle one in each column)**:**

Water Color	Recreation Potential	Physical Appearance
1 – Brown	1 – Beautiful	1 – Crystal Clear
2 – Blue/Green	2 – Minor Aesthetic Problems	2 – Some visible particulate matter or algae
3 – Green	3 – Swimming Impaired *	3 – Definite Algae/Particulate Matter imparting significant visibility loss and/or additional color to the water
4 – Yellow/ Green	4 – Would not Swim*	4 – High Algae levels – with limited Clarity, apparent mild odor, or scum
5 – Light Blue	5 – No Recreation Possible	5 – Severe Algae growth with strong odor or massive floating scums
6 – Clear		

**not based on temperature*

Weather (circle one in each column)**:**

Sky		Wind	
Sunny	(0-25% cloudy)	Calm	(0-5 mph, just until you can see surface ripples)
Partly Cloudy	(25-75% cloudy)	Light Breeze	(6-10 mph, ripples to waves, you can feel it)
Overcast	(75+% cloudy)	Windy	(11-15 mph, waves but NO whitecaps)

Comments/Water Quality Narrative (Add a narrative description to give context to your ratings and document any **normal** or **remarkable** conditions. Examples might include excessive pine pollen or needles, sediment coming from adjacent rivers, exceedingly calm conditions, etc.):

_____

_____

Quality Assurance/Quality Control (QA/QC) Plan

The Quality Assurance/Quality Control Plan is in place to ensure accurate and precise data measurements. The QA/QC provides confidence in the data generated for the Secchi Monitoring Program.

1. Secchi measurements should be made by trained personnel.
2. Internal Quality Control Checks for Technicians
    a. Follow procedure exactly as outlined in this document.
    b. Field sheets shall be filled in completely and correctly.
    c. Once a month, two technicians shall take simultaneous measurements to test accuracy.
    d. All measurements will be recorded. If measurements between two individuals are different by more than 20%, both readings will be recorded but a note will be added to flag the data.
    e. Conditions that may be a factor in differing measurements (i.e. windy, waves) should be documented and noted in the database.
3. External Quality Control Checks
    a. If multiple agencies/samplers are conducting the sampling, a replicate sampling event should be scheduled 1 to 2 times per season (for example between Northern Water and GCWIN).
    b. Data should be reviewed periodically; systematic bias should be noted and addressed if necessary.

APPENDIX 3 – FIELD PROTOCOL FOR PHOTOGRAPHS TO ACCOMPANY SECCHI MEASUREMENTS IN GRAND LAKE AND SHADOW MOUNTAIN RESERVOIR

Purpose

The Grand Lake Clarity Adaptive Management Committee (AMC) seeks to develop a means of drawing a connection between numerical parameters such as pH, turbidity, Secchi depth, dissolved oxygen, and chlorophyll-a, and what those numerical values translate to in terms the actual appearance of the water.

Site Locations

Grand Lake: GL-WES and GL-MID. Shadow Mountain: SM-DAM and SM-MID

Frequency

Once per week—Monday is recommended to afford ample time for photo download and transfer to Northern Water so that photos may be attached to reporting for Adaptive Management Committee calls.

Duration

July 1 – Sept. 11 at a minimum. In future years, photos to accompany spring runoff might also be instructive.

Equipment Required

Self-focusing underwater camera attached to flotation device. Computer with ability to download and transfer photographs.

Procedure

Camera shall be submerged just below the surface of the water, directly above, in line with, and facing the Secchi disc. The Secchi disk will be held at a depth of exactly 2’ and 4’ below the camera lens. Take up to 3 photographs of the Secchi disc at each of the depths and site locations. Photographs will be downloaded to a computer and clearly labeled with sight location, date, time of day, and depth of Secchi disc below camera lens. Photographs will be delivered to Northern Water together with the Secchi data per the annual Secchi contract for weekly incorporation into the AMC packet. Original photo record shall be maintained at GCWIN and made available on the GCWIN website.


Northern Water