Appendix E

Example Hydrographs

Upper Mississippi River Reservoir Operation Plan Evaluation (ROPE) Study - Example Hydrographs

Example hydrographs were selected and presented here to provide information regarding reservoir elevations for the existing and proposed operating plans. Hydrographs shown for actual measured water levels experienced under the existing operating plan are titled "….Historic Releases", and those simulated with a daily mass-balance model for the existing and proposed operating plans are titled "….Proposed Operation…".

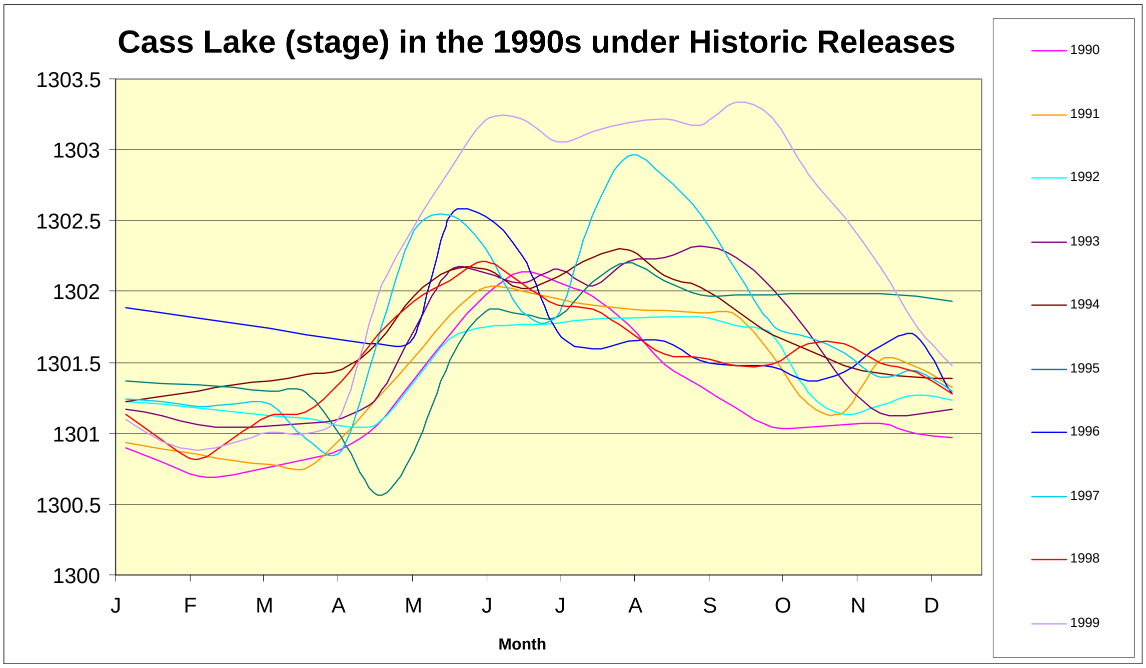
Historic release hydrographs are presented for the 1990's and 1980's as examples of water level variability under the existing operating plan. These hydrographs are reproduced from actual measured data. They show that water levels fluctuate due to hydrologic conditions and that the dams have a limited amount of "control" over reservoir water levels.

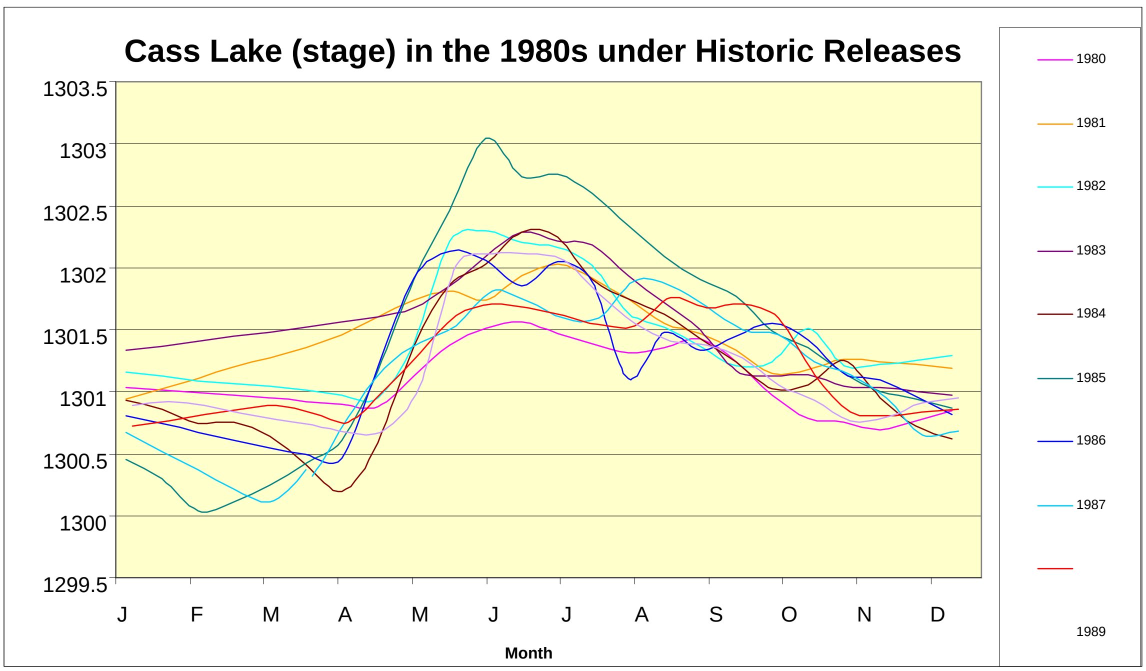
Simulated hydrographs were created with a daily mass-balance model for the existing operating plan and for the proposed plan. The heavy red lines labeled as the "Calculated (Current)" in the legends show the simulated water levels under the existing operating plan. The thinner solid black lines labeled as "Proposed" in the legends show the simulated water levels under the proposed operating rules. The dashed black lines labeled as the "Target (Proposed)" in the legends show the targeted water levels under normal conditions under the proposed operating plan.

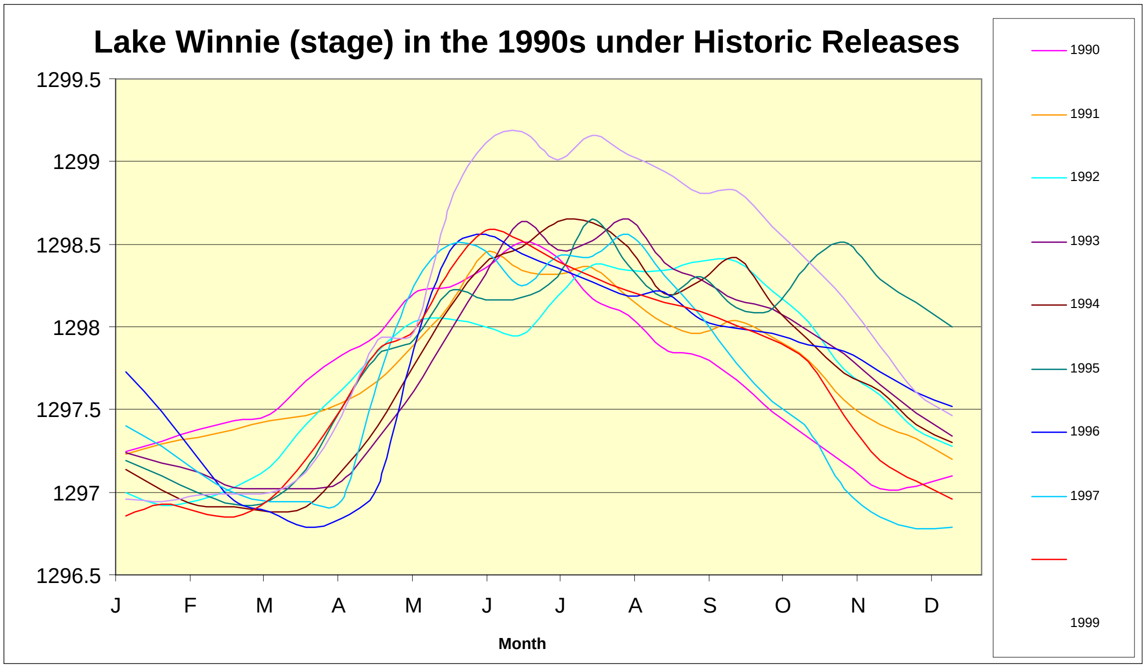
The simulated levels under the existing plan do not directly match the actual measured data. There is a good deal of operator discretion that is applied in day-to-day operations that cannot be represented in a numerical model. Information such as weather forecasts and professional judgment are used by an operator to better meet operating goals, but cannot be built into a simple numerical model.

The mass-balance model was calibrated to reasonably match historic levels in many years so that the results are useful for determining basic differences between the existing and proposed operating plans. These are particularly useful during times of relatively normal or low inflows, such as during the summer months. Results during the spring when inflows can spike to high levels are somewhat less useful and require careful interpretation. Accurate interpretation of these results requires careful consideration of numerous factors and a good understanding of how the physical system and the numerical model function.

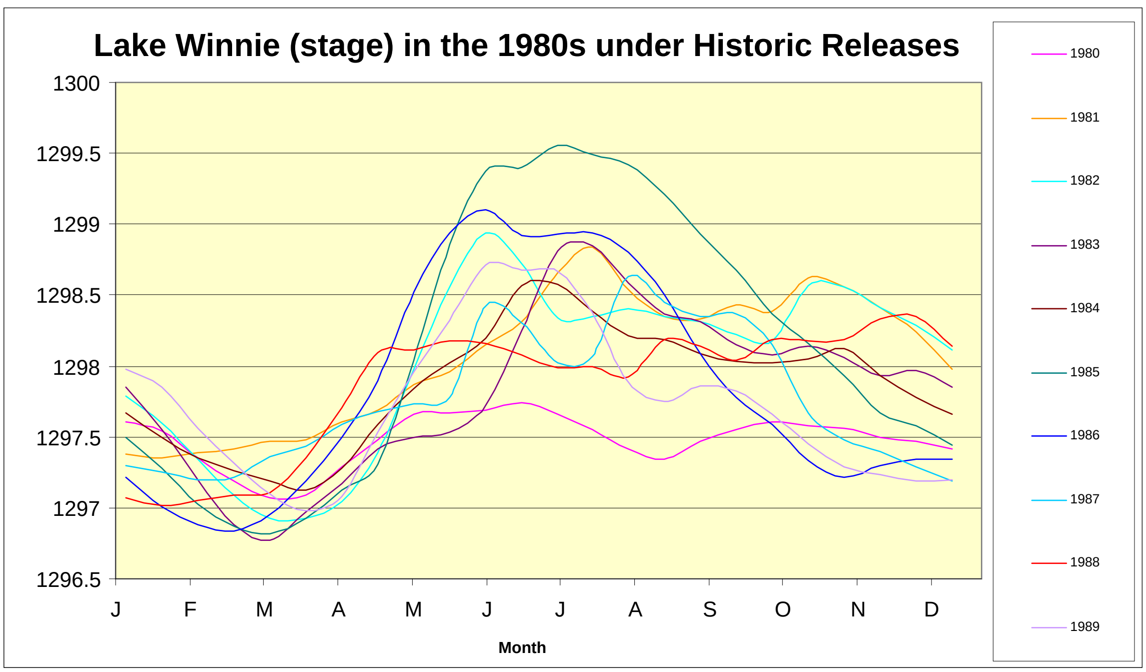
Because the vast amount of data available and because the model does not calibrate well for all years, only a small subset of years are presented here as examples. The data presented here are for years where the model calibration was satisfactory. An attempt was made to provide data for normal to wet, and for dry years. Dry year data includes 2007, 2006, 1988, and 1976; all other years were considered normal or wet.


Cass Lake (stage) in the 1990s under Historic Releases
1303.5
1303
1302.5
1302
1301.5
1301
1300.5
1300
J
F
M
A
M
J
J
A
S
O
N
D
Month
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

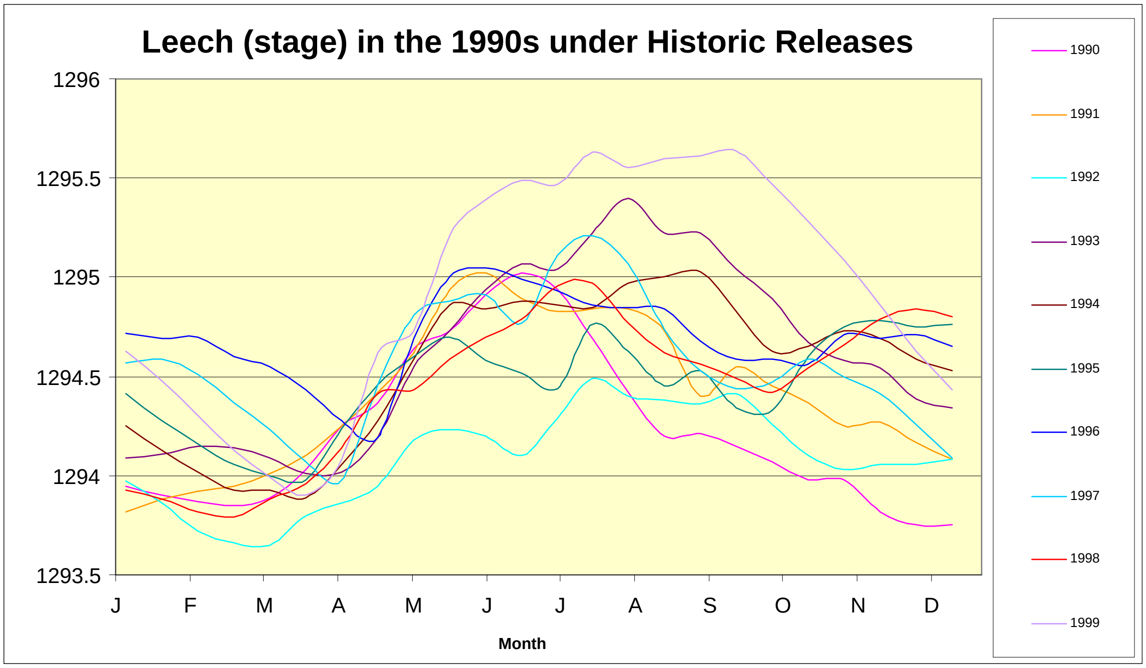

Cass Lake (stage) in the 1980s under Historic Releases
1303.5
1303
1302.5
1302
1301.5
1301
1300.5
1300
1299.5
J
F
M
A
M
J
J
A
S
O
N
D
Month
1980
1981
1982
1983
1984
1985
1986
1987
1989



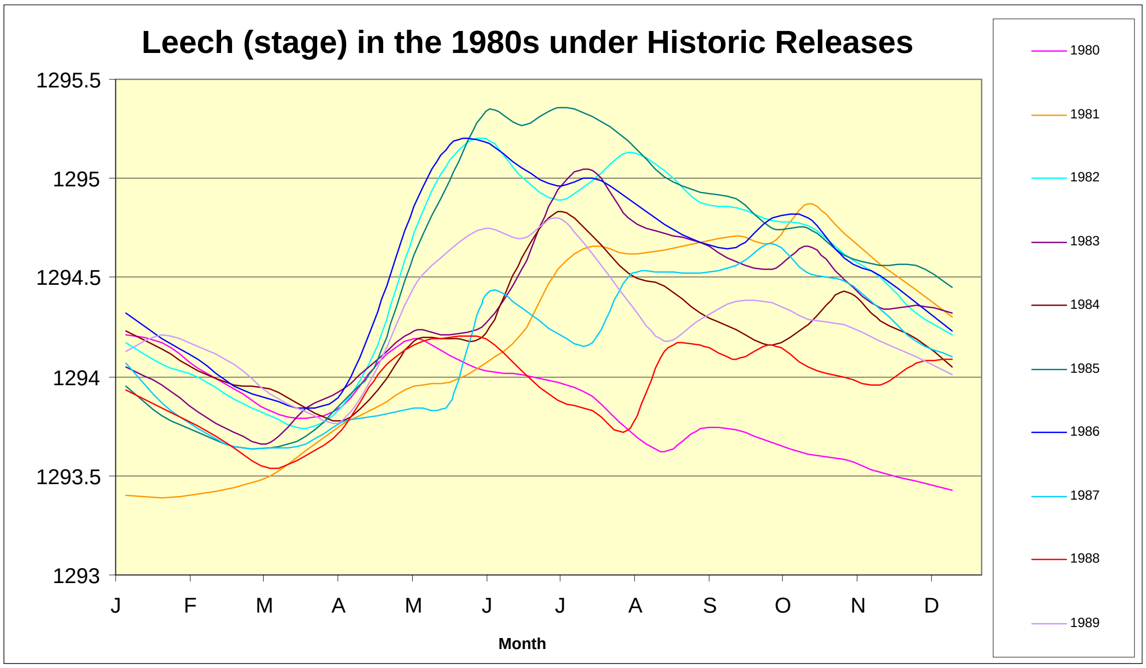
Lake Winnie (stage) in the 1990s under Historic Releases
1299.5
1299
1298.5
1298
1297.5
1297
1296.5
J
F
M
A
M
J
J
A
S
O
N
D
Month
1990
1991
1992
1993
1994
1995
1996
1997
1999



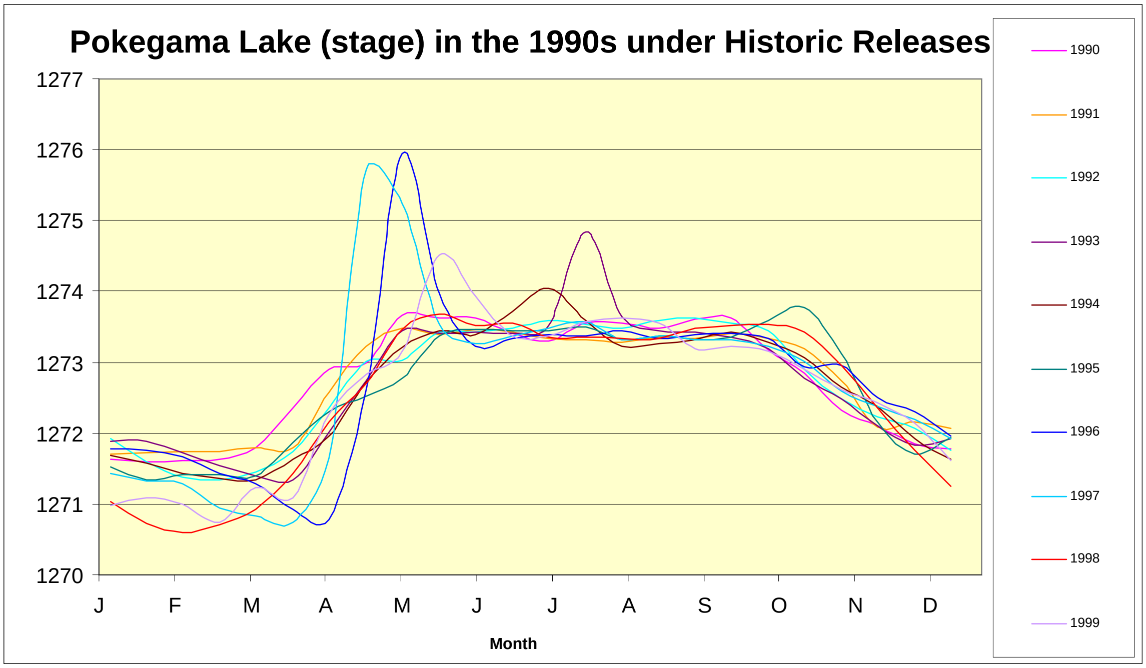
Lake Winnie (stage) in the 1980s under Historic Releases
1300
1299.5
1299
1298.5
1298
1297.5
1297
1296.5
J
F
M
A
M
J
J
A
S
O
N
D
Month
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989

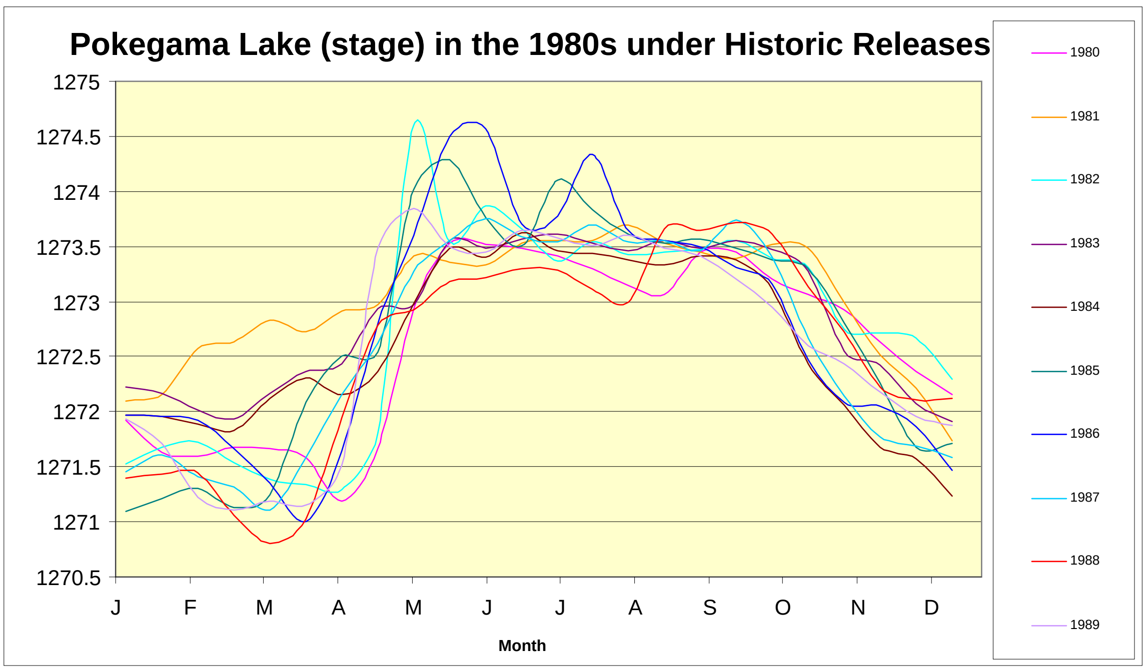


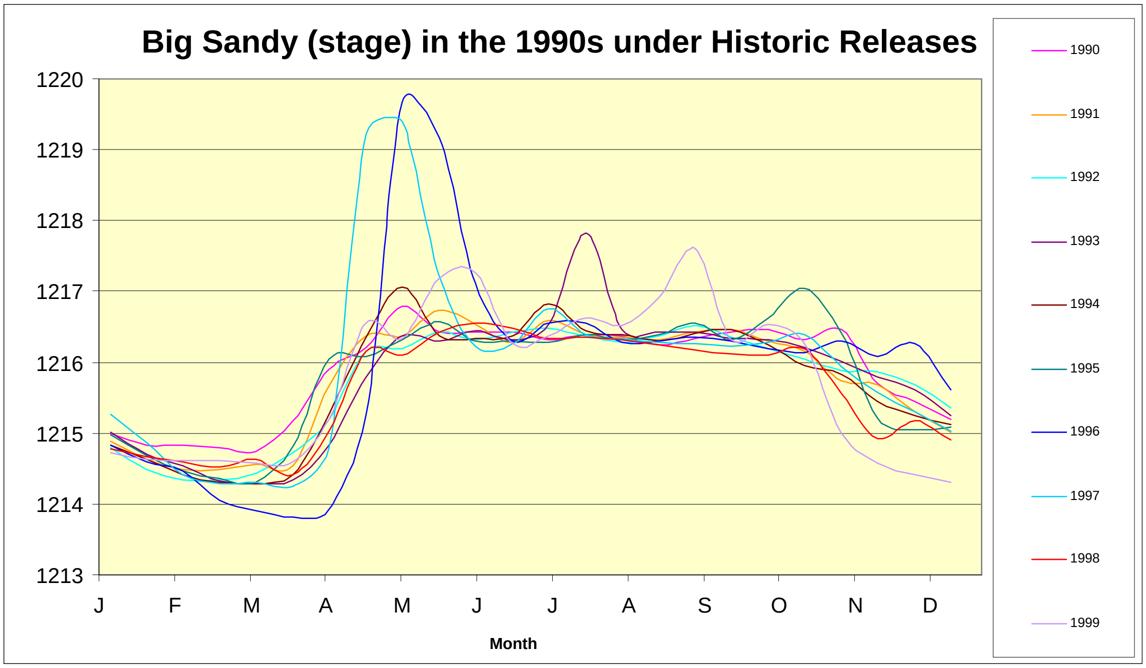
Leech (stage) in the 1990s under Historic Releases
1296
1295.5
1295
1294.5
1294
1293.5
J
F
M
A
M
J
J
A
S
O
N
D
Month
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

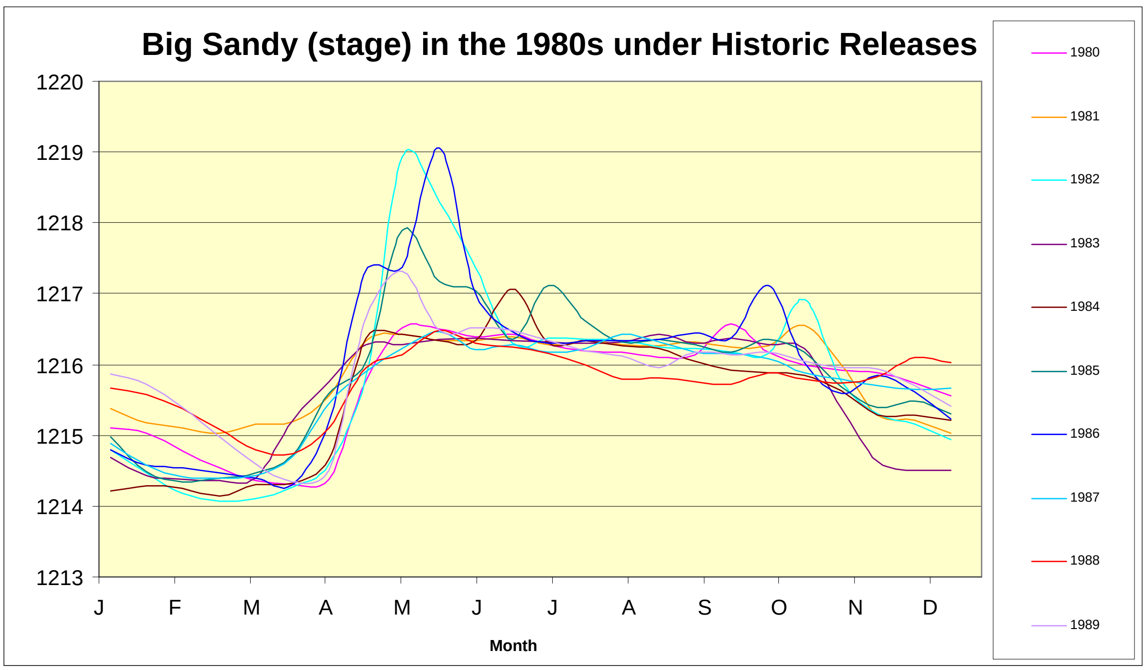


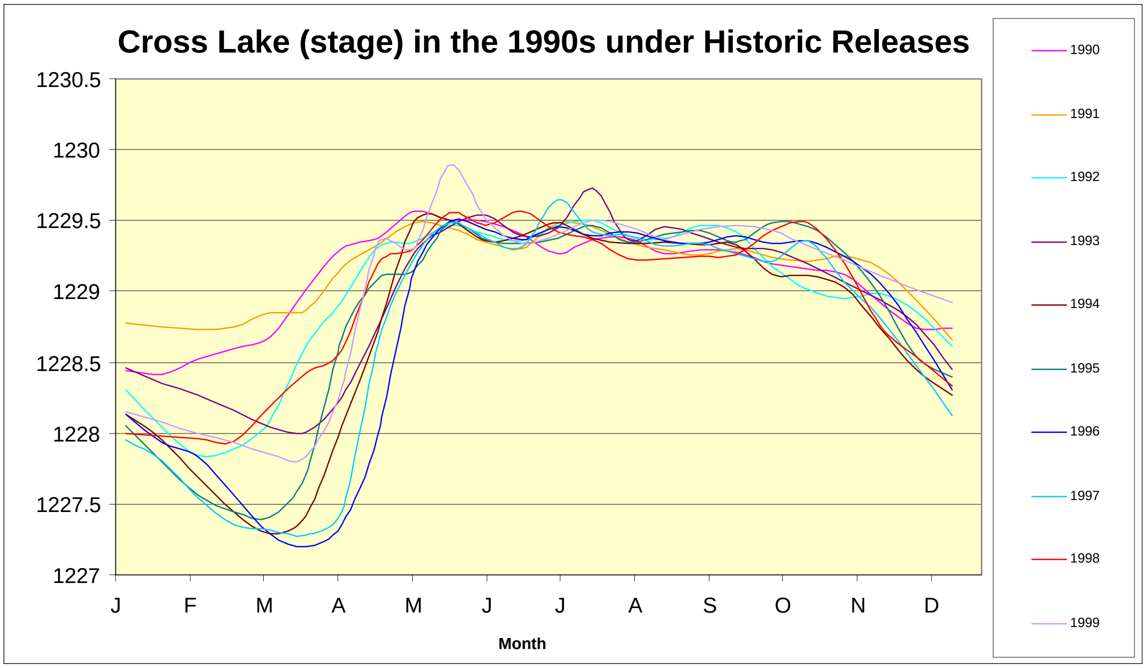
Leech (stage) in the 1980s under Historic Releases
1295.5
1295
1294.5
1294
1293.5
1293
J
F
M
A
M
J
J
A
S
O
N
D
Month
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989

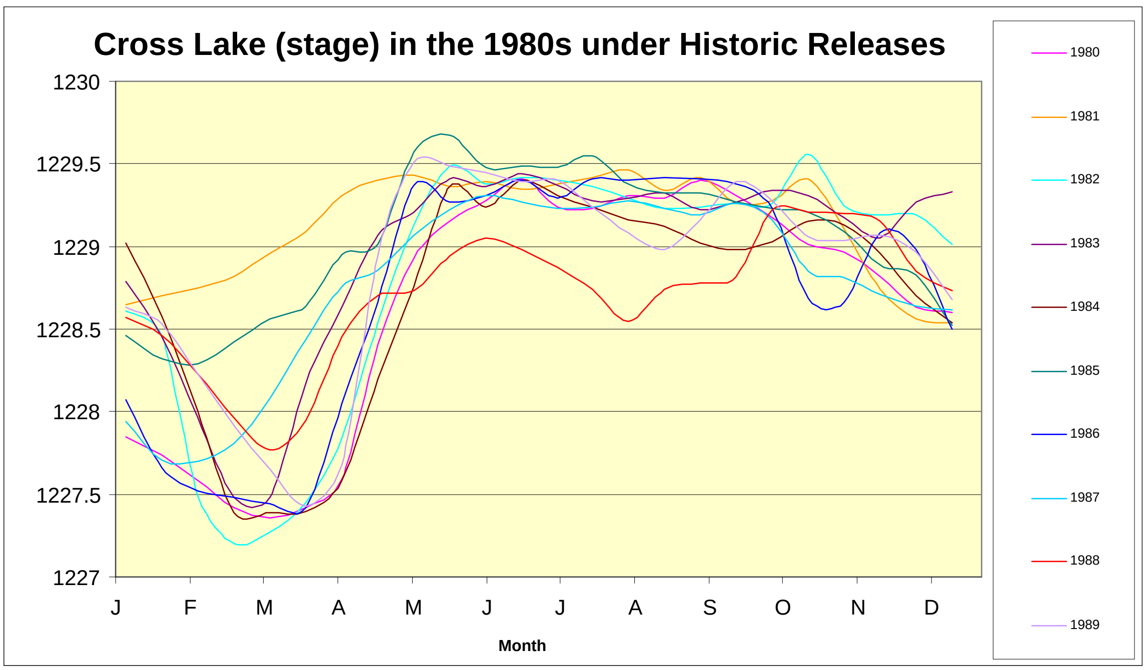

Pokegama Lake (stage) in the 1990s under Historic Releases
1277
1276
1275
1274
1273
1272
1271
1270
J
F
M
A
M
J
J
A
S
O
N
D
Month
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

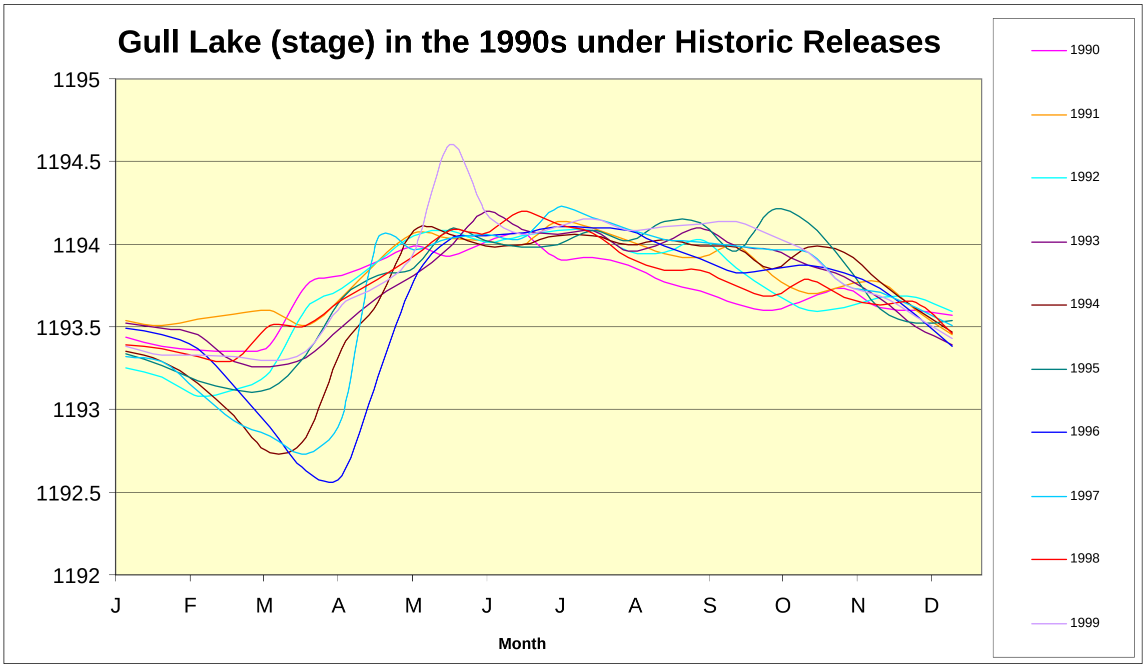

Pokegama Lake (stage) in the 1980s under Historic Releases
1275
1274.5
1274
1273.5
1273
1272.5
1272
1271.5
1271
1270.5
J
F
M
A
M
J
J
A
S
O
N
D
Month
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989


Big Sandy (stage) in the 1990s under Historic Releases
1220
1219
1218
1217
1216
1215
1214
1213
J
F
M
A
M
J
J
A
S
O
N
D
Month
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

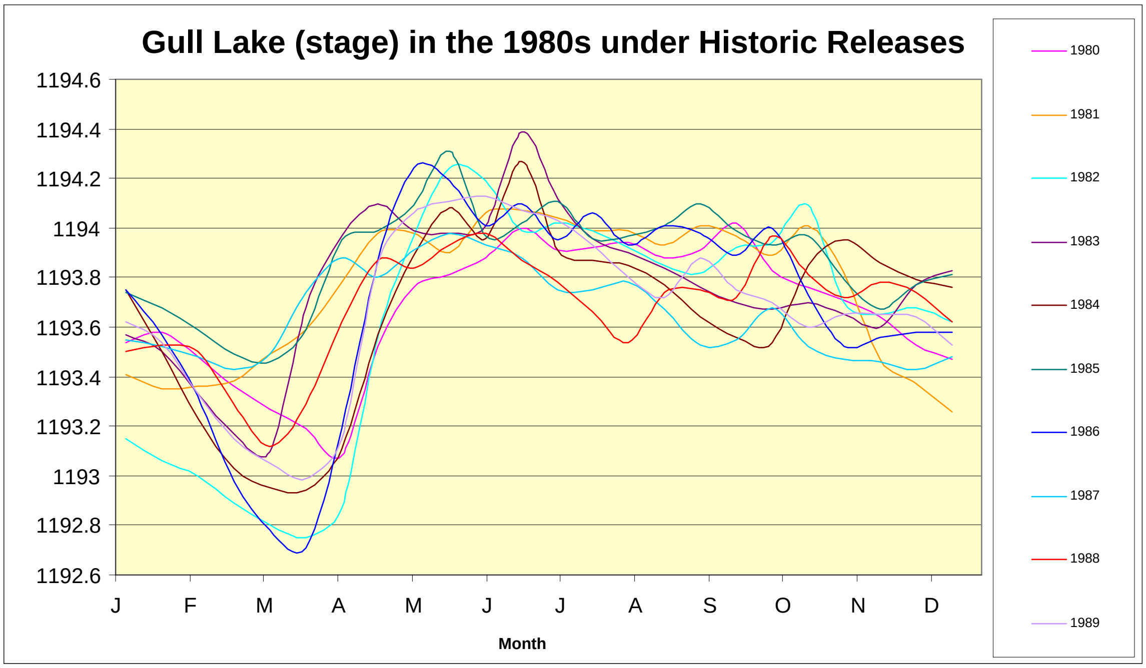

Big Sandy (stage) in the 1980s under Historic Releases
1220
1219
1218
1217
1216
1215
1214
1213
J
F
M
A
M
J
J
A
S
O
N
D
Month
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989


Cross Lake (stage) in the 1990s under Historic Releases
1230.5
1230
1229.5
1229
1228.5
1228
1227.5
1227
J
F
M
A
M
J
J
A
S
O
N
D
Month
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

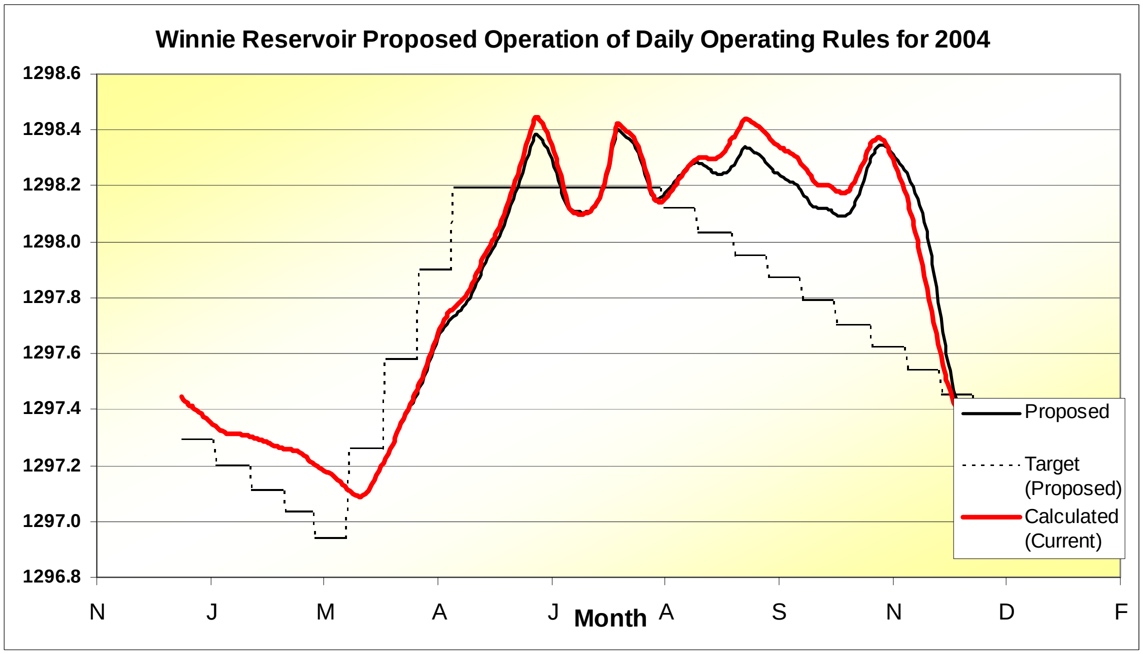

Cross Lake (stage) in the 1980s under Historic Releases
1230
1229.5
1229
1228.5
1228
1227.5
1227
J
F
M
A
M
J
J
A
S
O
N
D
Month
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989

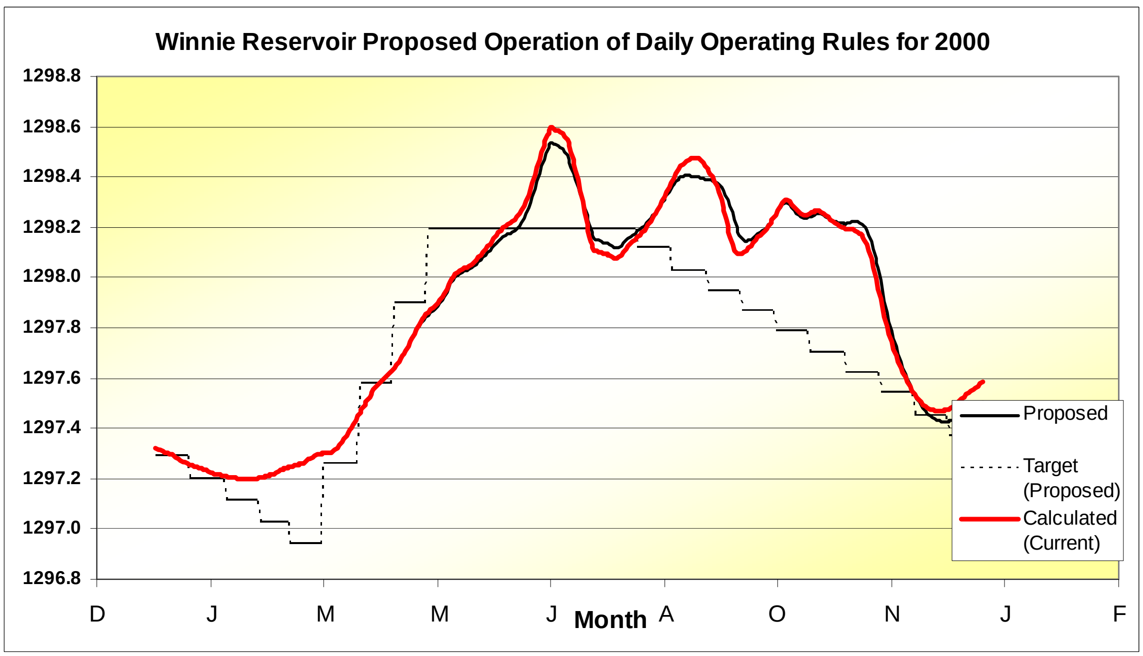


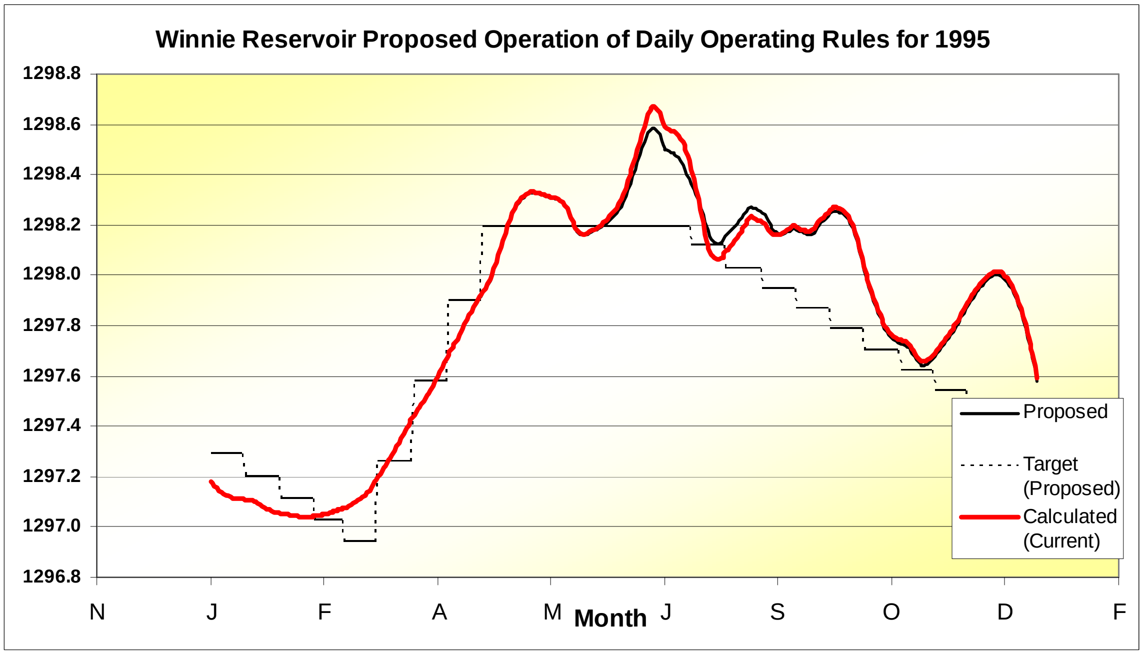
Gull Lake (stage) in the 1990s under Historic Releases
1195
1194.5
1194
1193.5
1193
1192.5
1192
J F M A M J J A S O N D
Month
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999



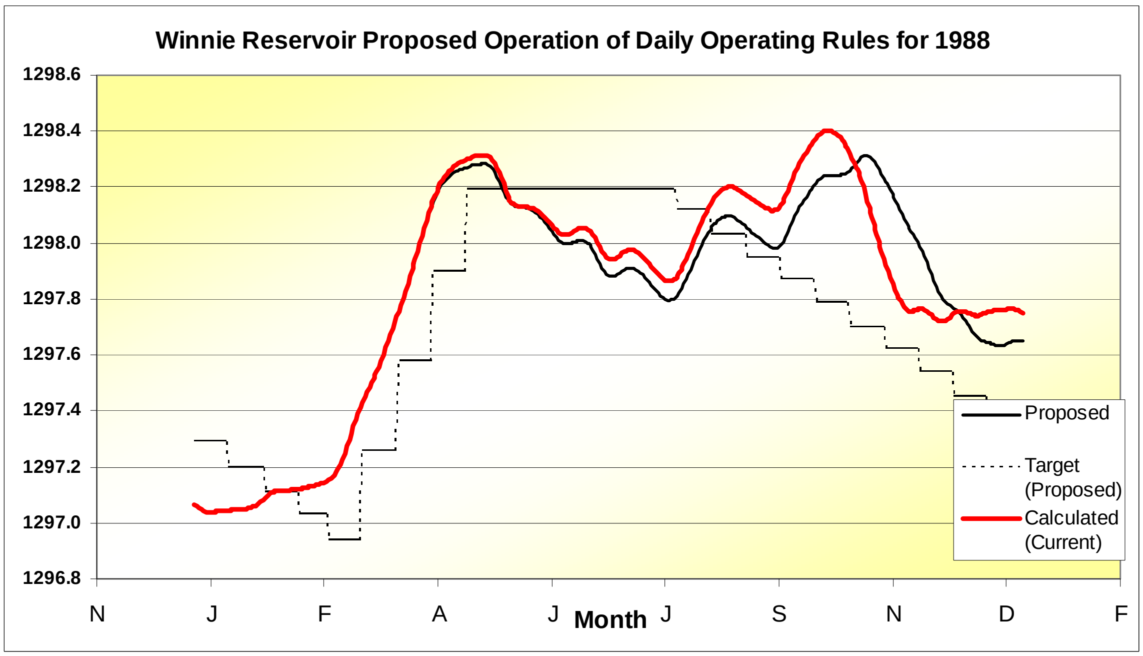
Gull Lake (stage) in the 1980s under Historic Releases
1194.6
1194.4
1194.2
1194
1193.8
1193.6
1193.4
1193.2
1193
1192.8
1192.6
J F M A M J J A S O N D
Month
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989


Winnie Reservoir Proposed Operation of Daily Operating Rules for 2004
1298.6
1298.4
1298.2
1298.0
1297.8
1297.6
1297.4
1297.2
1297.0
1296.8
N
J
M
A
J
Month
A
S
N
D
F
Proposed
Target (Proposed)
Calculated (Current)

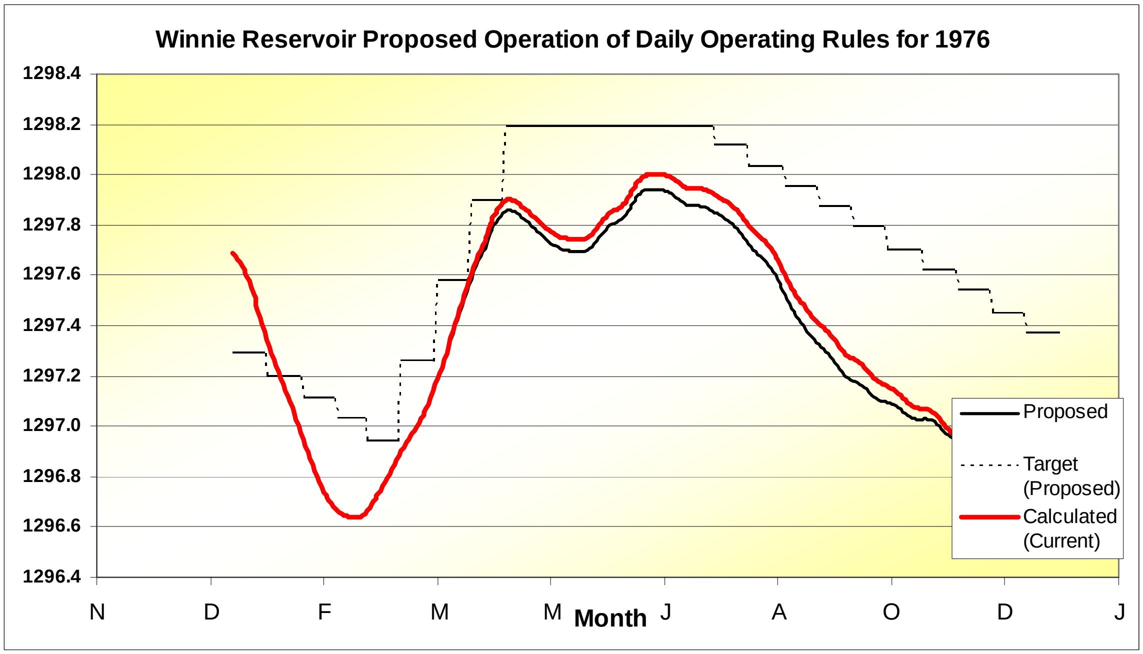

Winnie Reservoir Proposed Operation of Daily Operating Rules for 2000
1298.8
1298.6
1298.4
1298.2
1298.0
1297.8
1297.6
1297.4
1297.2
1297.0
1296.8
D
J
M
M
J
Month
A
O
N
J
F
Proposed
Target (Proposed)
Calculated (Current)

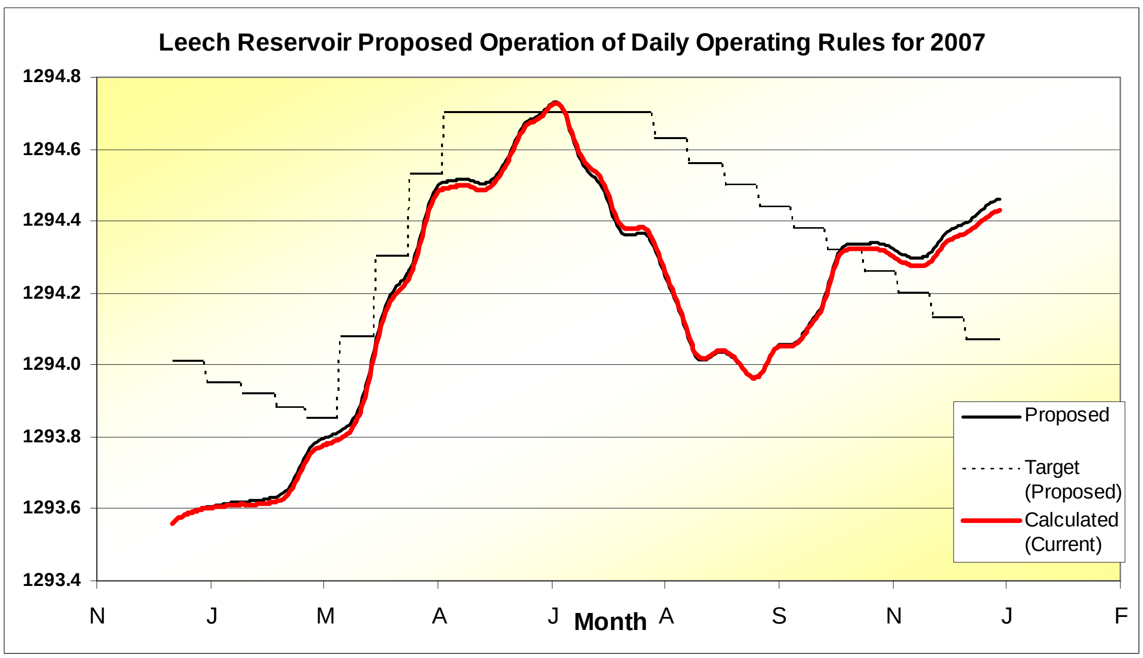


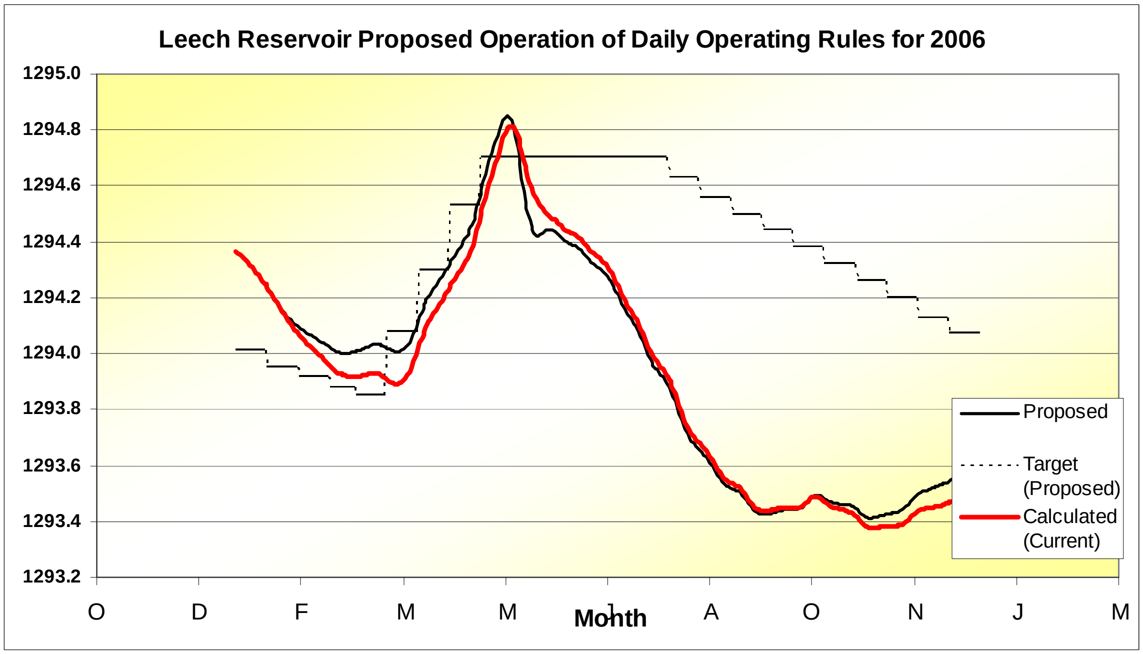
Winnie Reservoir Proposed Operation of Daily Operating Rules for 1995
1298.8
1298.6
1298.4
1298.2
1298.0
1297.8
1297.6
1297.4
1297.2
1297.0
1296.8
N
J
F
A
M
Month
J
S
O
D
F
Proposed
Target (Proposed)
Calculated (Current)

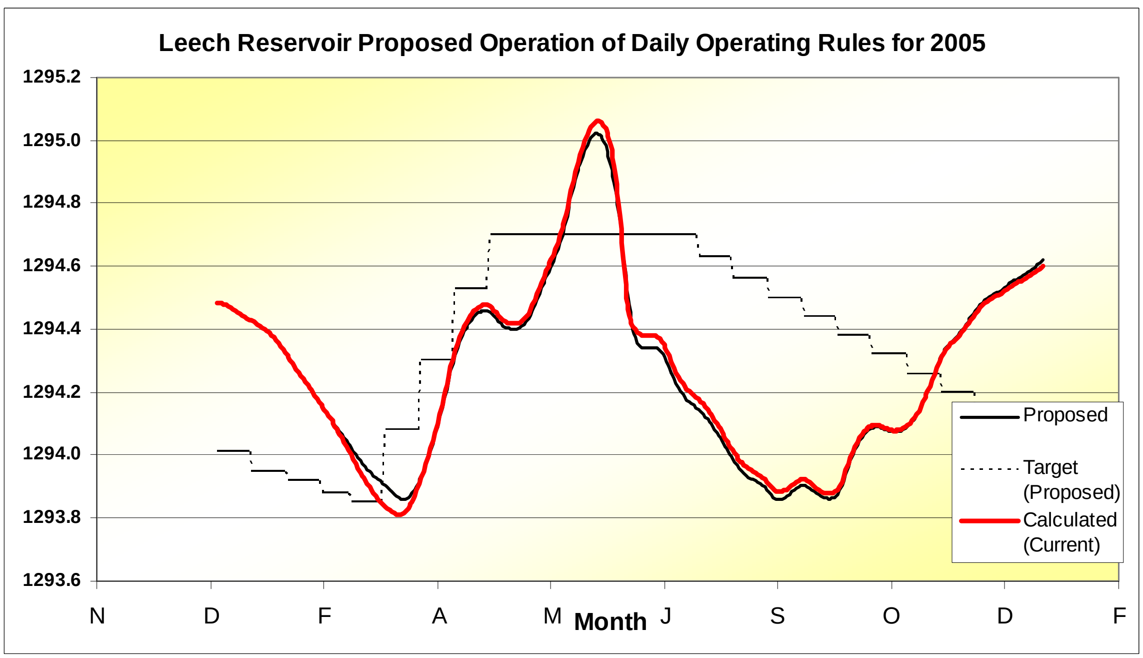


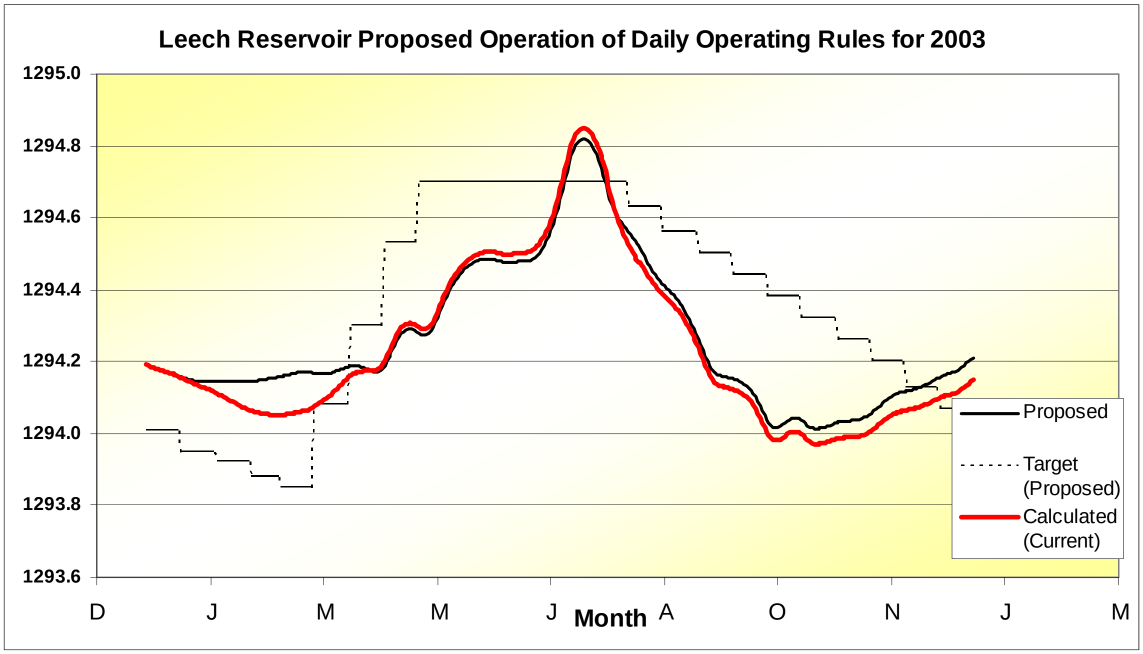
Winnie Reservoir Proposed Operation of Daily Operating Rules for 1988
1298.6
1298.4
1298.2
1298.0
1297.8
1297.6
1297.4
1297.2
1297.0
1296.8
N
J
F
A
J
Month
J
S
N
D
F
Proposed
Target (Proposed)
Calculated (Current)

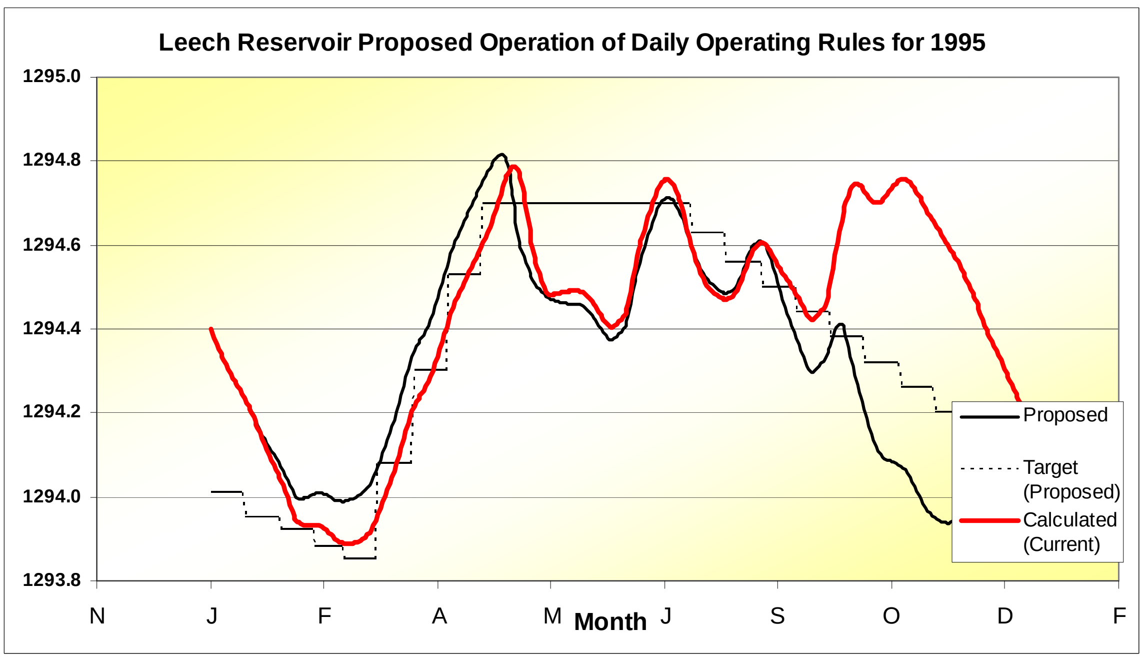

Winnie Reservoir Proposed Operation of Daily Operating Rules for 1976
1298.4
1298.2
1298.0
1297.8
1297.6
1297.4
1297.2
1297.0
1296.8
1296.6
1296.4
N
D
F
M
M
Month
J
A
O
D
J
Proposed
Target (Proposed)
Calculated (Current)

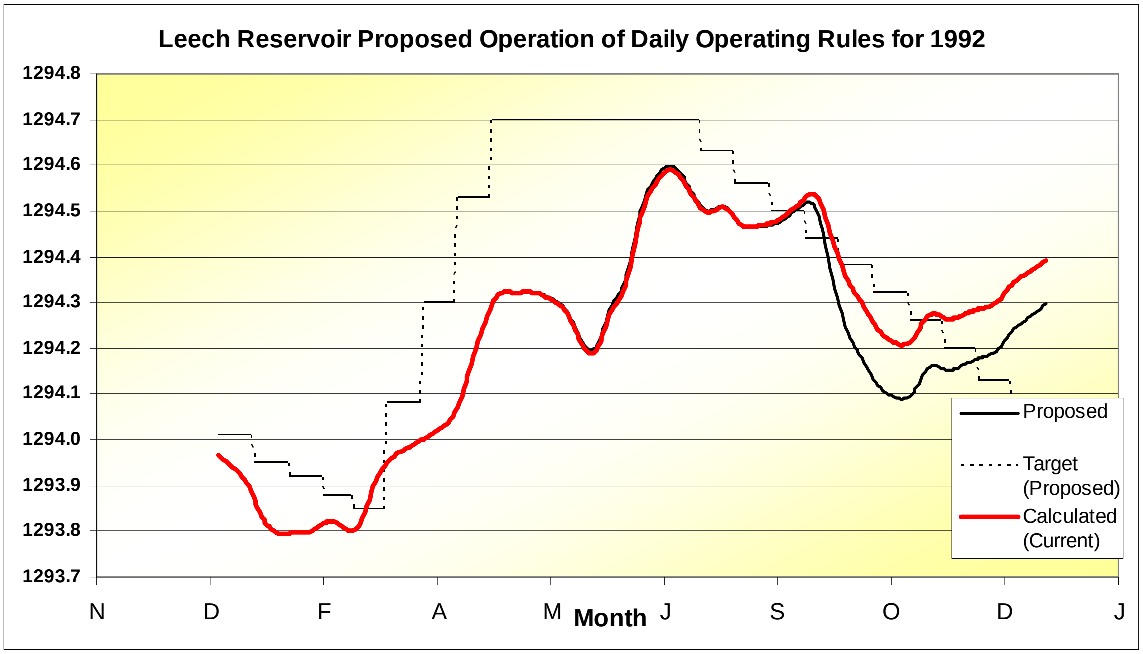

Leech Reservoir Proposed Operation of Daily Operating Rules for 2007
1294.8
1294.6
1294.4
1294.2
1294.0
1293.8
1293.6
1293.4
N
J
M
A
J
Month
A
S
N
J
F
Proposed
Target (Proposed)
Calculated (Current)

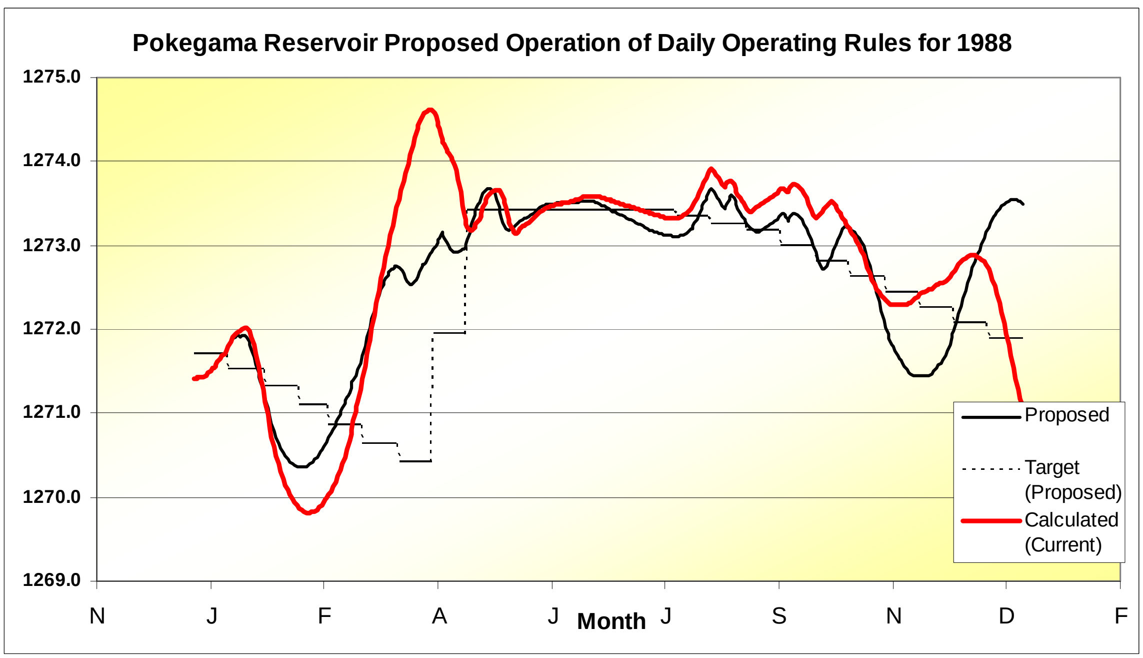

Leech Reservoir Proposed Operation of Daily Operating Rules for 2006
1295.0
1294.8
1294.6
1294.4
1294.2
1294.0
1293.8
1293.6
1293.4
1293.2
O
D
F
M
M
J
Month
A
O
N
J
M
Proposed
Target (Proposed)
Calculated (Current)

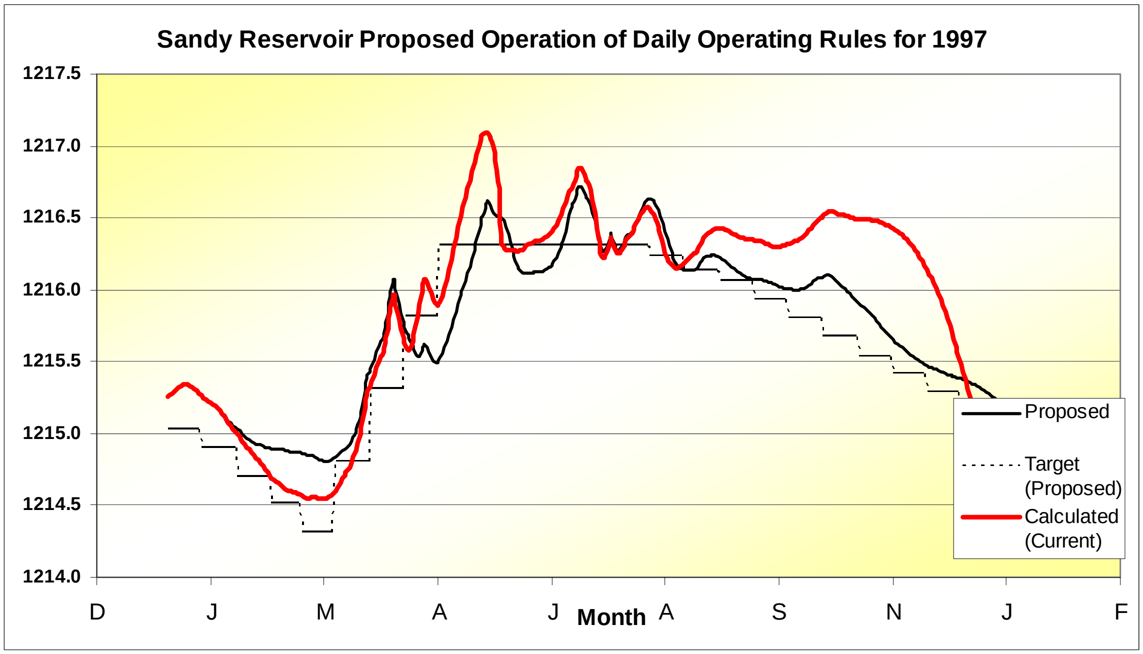

Leech Reservoir Proposed Operation of Daily Operating Rules for 2005
1295.2
1295.0
1294.8
1294.6
1294.4
1294.2
1294.0
1293.8
1293.6
N
D
F
A
M
Month
J
S
O
D
F
Proposed
Target (Proposed)
Calculated (Current)

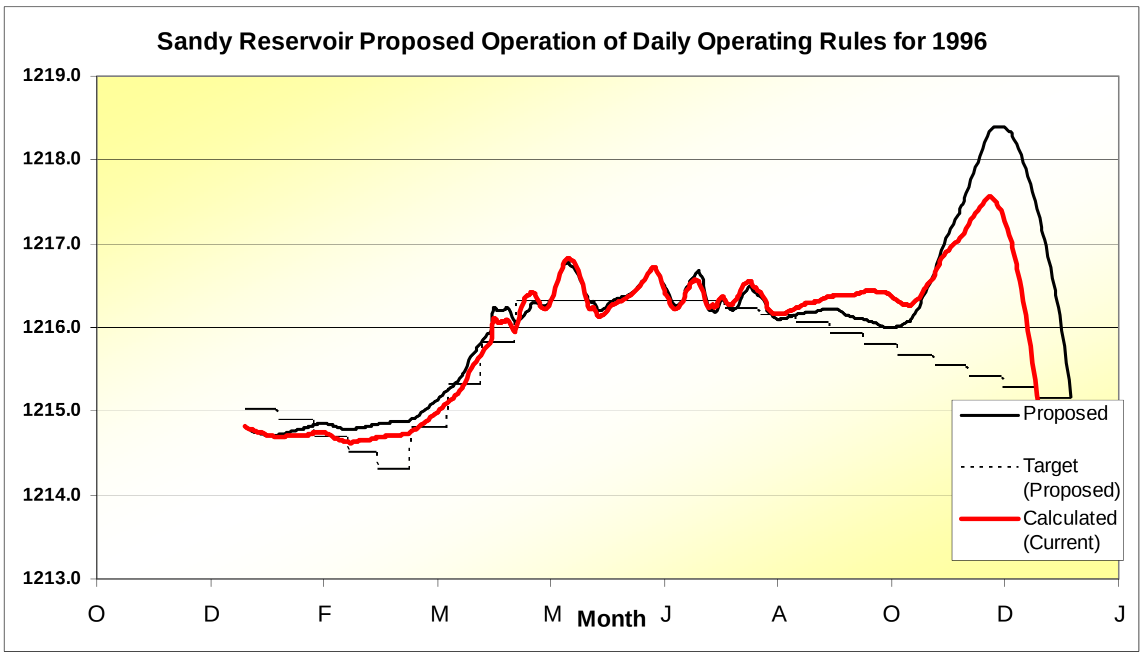

Leech Reservoir Proposed Operation of Daily Operating Rules for 2003
1295.0
1294.8
1294.6
1294.4
1294.2
1294.0
1293.8
1293.6
D
J
M
M
J
Month
A
O
N
J
M
Proposed
Target (Proposed)
Calculated (Current)

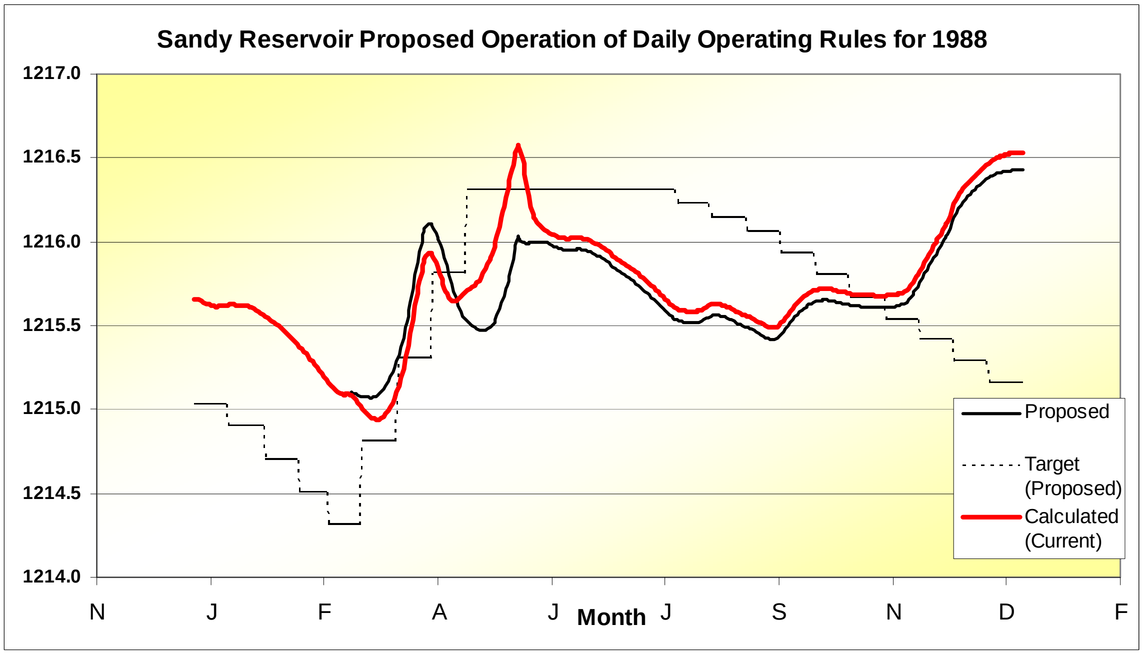

Leech Reservoir Proposed Operation of Daily Operating Rules for 1995
1295.0
1294.8
1294.6
1294.4
1294.2
1294.0
1293.8
N
J
F
A
M
Month
J
S
O
D
F
Proposed
Target (Proposed)
Calculated (Current)

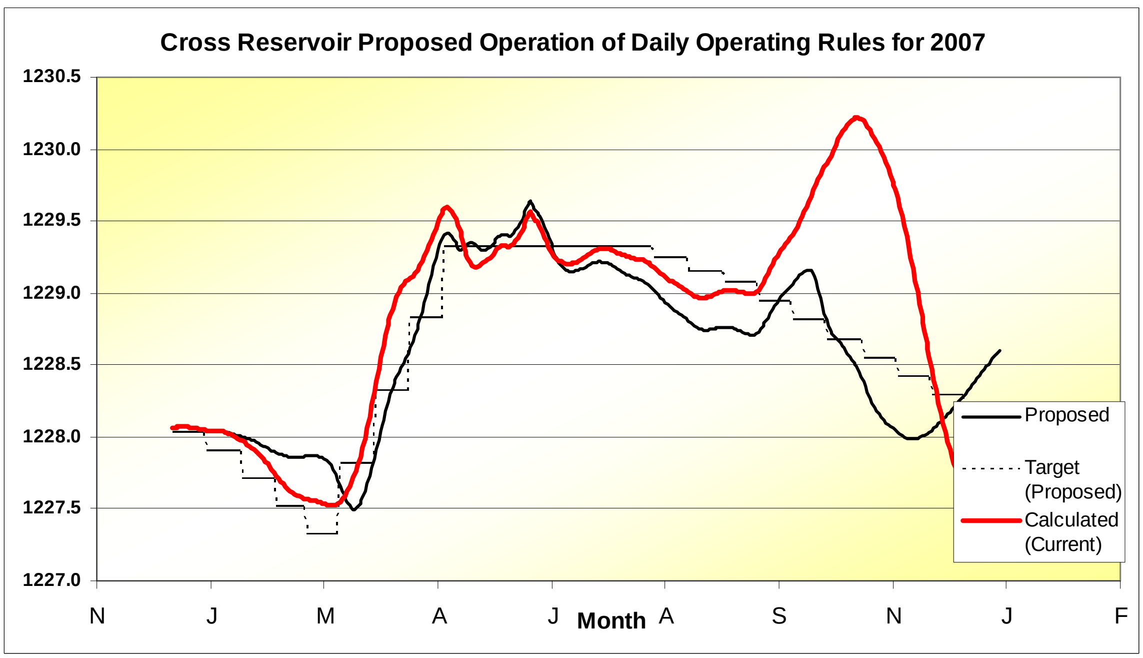

Leech Reservoir Proposed Operation of Daily Operating Rules for 1992
1294.8
1294.7
1294.6
1294.5
1294.4
1294.3
1294.2
1294.1
1294.0
1293.9
1293.8
1293.7
N
D
F
A
M
Month
J
S
O
D
J
Proposed
Target (Proposed)
Calculated (Current)

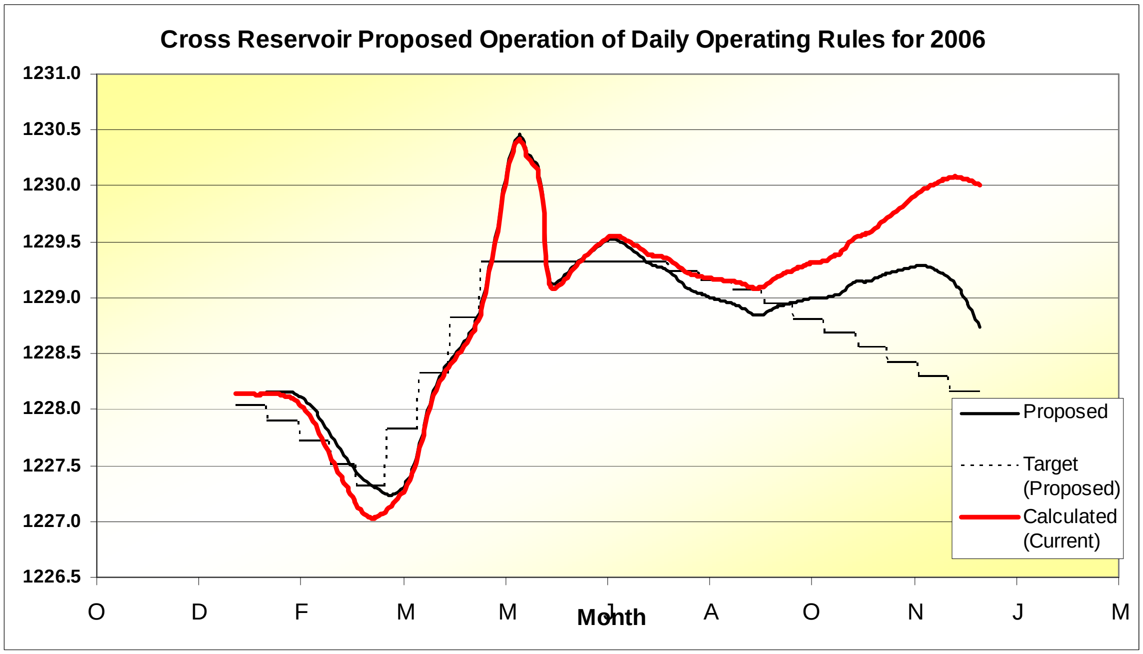

Pokegama Reservoir Proposed Operation of Daily Operating Rules for 1988
1275.0
1274.0
1273.0
1272.0
1271.0
1270.0
1269.0
N
J
F
A
J
Month
J
S
N
D
F
Proposed
Target (Proposed)
Calculated (Current)


Sandy Reservoir Proposed Operation of Daily Operating Rules for 1997
1217.5
1217.0
1216.5
1216.0
1215.5
1215.0
1214.5
1214.0
D
J
M
A
J
Month
A
S
N
J
F
Proposed
Target (Proposed)
Calculated (Current)

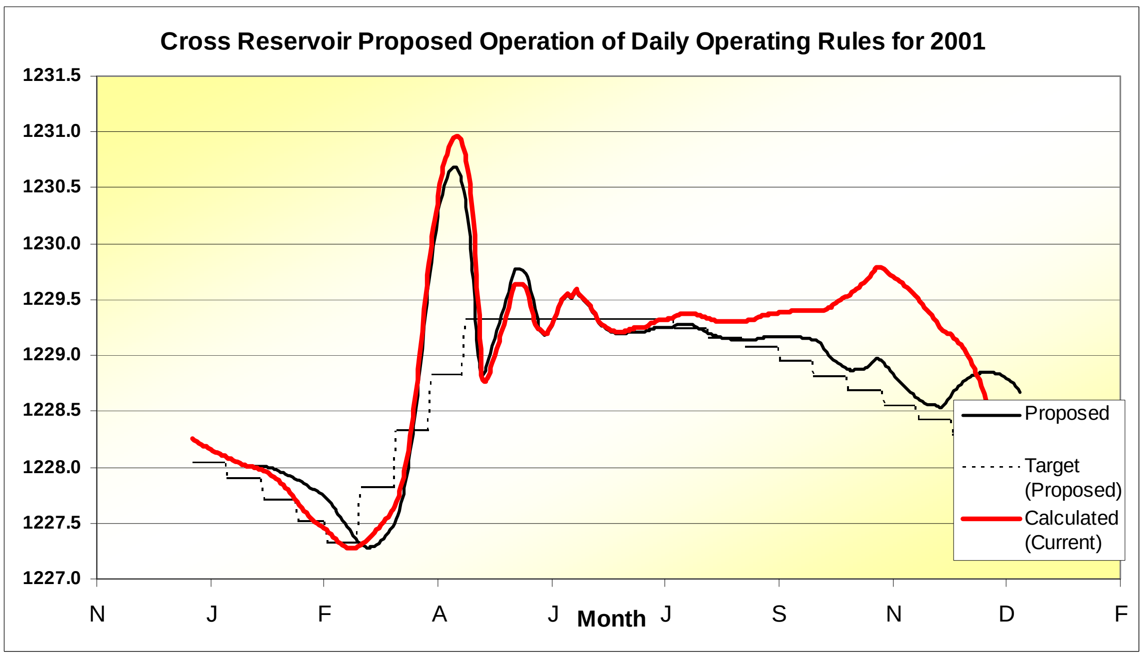

Sandy Reservoir Proposed Operation of Daily Operating Rules for 1996
1219.0
1218.0
1217.0
1216.0
1215.0
1214.0
1213.0
O
D
F
M
M
Month
J
A
O
D
J
Proposed
Target (Proposed)
Calculated (Current)


Sandy Reservoir Proposed Operation of Daily Operating Rules for 1988
1217.0
1216.5
1216.0
1215.5
1215.0
1214.5
1214.0
N
J
F
A
J
Month
J
S
N
D
F
Proposed
Target (Proposed)
Calculated (Current)

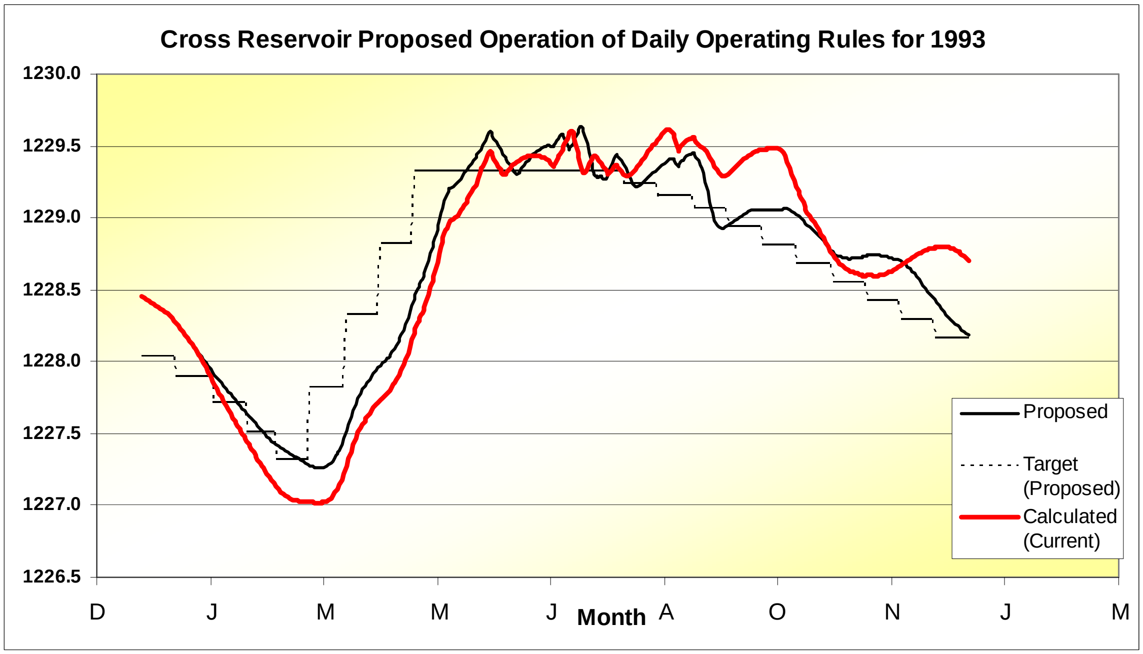

Cross Reservoir Proposed Operation of Daily Operating Rules for 2007
1230.5
1230.0
1229.5
1229.0
1228.5
1228.0
1227.5
1227.0
N
J
M
A
J
Month
A
S
N
J
F
Proposed
Target (Proposed)
Calculated (Current)

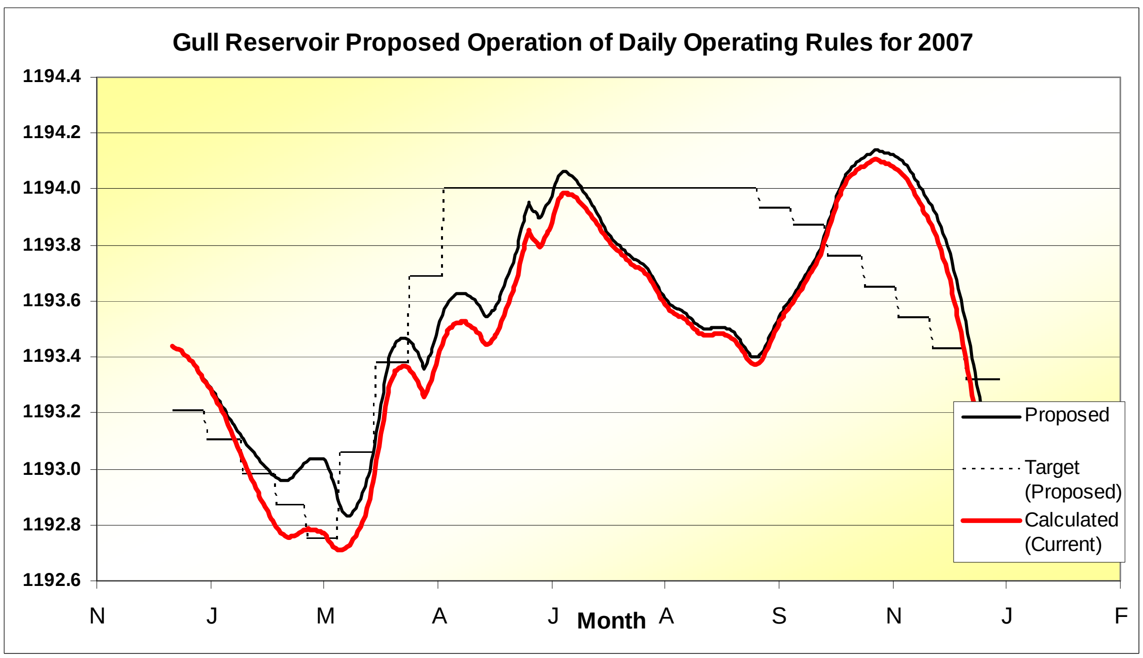


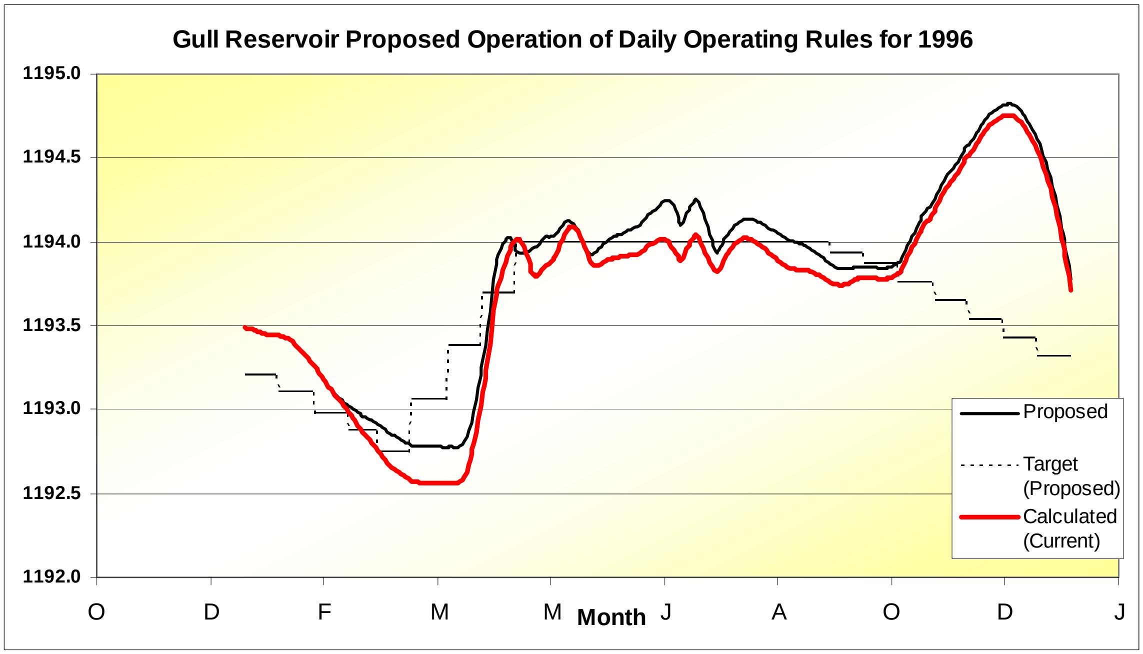
Cross Reservoir Proposed Operation of Daily Operating Rules for 2006
1231.0
1230.5
1230.0
1229.5
1229.0
1228.5
1228.0
1227.5
1227.0
1226.5
O
D
F
M
M
J
A
O
N
J
M
Month
Proposed
Target (Proposed)
Calculated (Current)

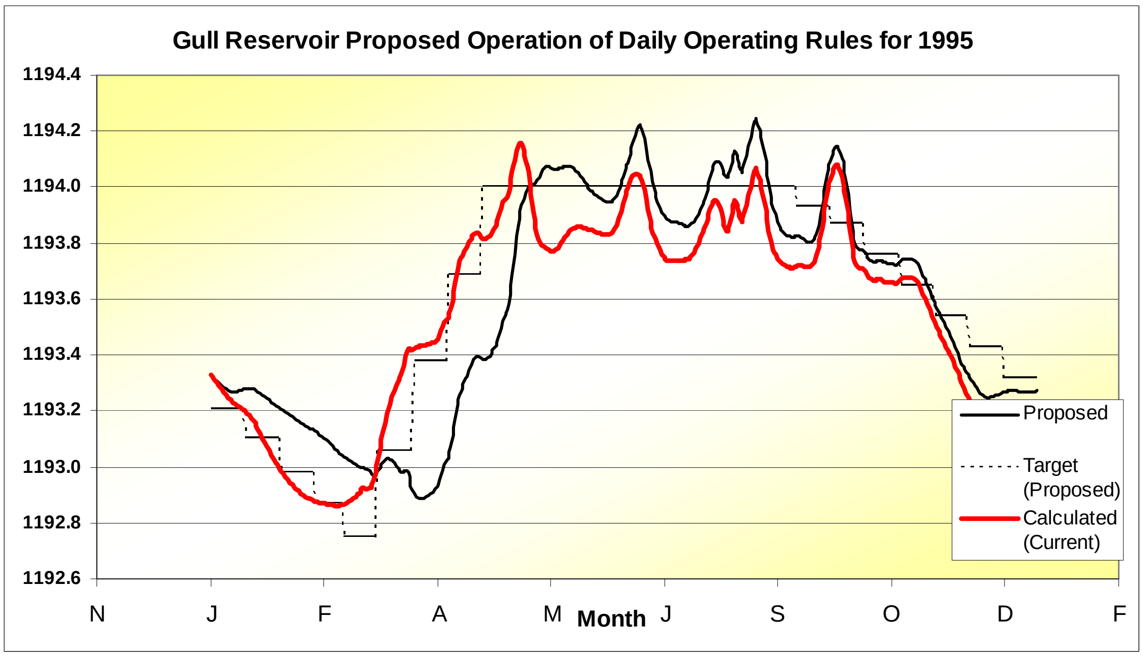


Cross Reservoir Proposed Operation of Daily Operating Rules for 2001
1231.5
1231.0
1230.5
1230.0
1229.5
1229.0
1228.5
1228.0
1227.5
1227.0
N
J
F
A
J
J
S
N
D
F
Month
Proposed
Target (Proposed)
Calculated (Current)


Cross Reservoir Proposed Operation of Daily Operating Rules for 1993
1230.0
1229.5
1229.0
1228.5
1228.0
1227.5
1227.0
1226.5
D
J
M
M
J
Month
A
O
N
J
M
Proposed
Target (Proposed)
Calculated (Current)


Gull Reservoir Proposed Operation of Daily Operating Rules for 2007
1194.4
1194.2
1194.0
1193.8
1193.6
1193.4
1193.2
1193.0
1192.8
1192.6
N
J
M
A
J
Month
A
S
N
J
F
Proposed
Target (Proposed)
Calculated (Current)


Gull Reservoir Proposed Operation of Daily Operating Rules for 1996
1195.0
1194.5
1194.0
1193.5
1193.0
1192.5
1192.0
O
D
F
M
M
Month
J
A
O
D
J
Proposed
Target
(Proposed)
Calculated
(Current)


Gull Reservoir Proposed Operation of Daily Operating Rules for 1995
1194.4
1194.2
1194.0
1193.8
1193.6
1193.4
1193.2
1193.0
1192.8
1192.6
N
J
F
A
M
Month
J
S
O
D
F
Proposed
Target
(Proposed)
Calculated
(Current)

Appendix F

Sandy Lake Flood Operation Evaluation

20 February 2008

To: Whom It May Concern
From: Kenton Spading
Subject: How often can Sandy Lake Dam follow the Aitkin Flood Control Guide Curves?

Plates 7-9 and 7-10 in the January 2003 Water Control Manual for Big Sandy Lake Dam contain Flood Control Guide Curves for operating Big Sandy Lake and Pokegama Lake Dam for flood control at Aitkin, MN (see attachments, the curves are also in the Pokegama manual). Since the guide curves were proposed in approx. 1956, it has proven very difficult if not impossible to operate Sandy Dam in accordance with the guide curves. This is due to the fact that the Mississippi River backwaters up to Sandy Lake Dam and during large floods it submerges Sandy's gates (in the tailwater) restricting the outflow. The guide curves begin at an Aitkin stage of approx. 12 feet which corresponds to Aitkin's National Weather Service flood stage (presently, very little damage occurs 12 ft.). The attached documents represent a graphical analysis of the utility of operating Sandy Lake Dam in accordance with the guide curves.

The period of record at the Aitkin USGS gage extends from 1945 to the present. During that 62 year period there were 32 runoff events that exceeded a stage of 12 feet at Aitkin (see attachment). Sandy Lake Dam's gates were submerged in all of those events although in 9 of them a limited amount of control was available (see attached plots). Seven (7) of the nine (9) events that offered some control at Sandy Lake Dam were events that culminated in stages at Aitkin that were less than 14 feet. Assuming that the guide curves were in place since 1945, the period of record clearly shows that there is limited utility in trying to operate Sandy for the existing guide curve (or likely for any curve) for events at Aitkin above 14 feet. The ability to follow the curve below 14 feet is also very limited.

Over the years, regulators have learned that the best approach is to release as much water as possible from Sandy Lake Dam early in the flood event so that when the tailwater/gates eventually submerge the maximum amount of storage is available in Sandy Lake Reservoir.

In some years, if Sandy Lake is high, caution must exercised to not increase the discharge out of Pokegama too aggressively in an effort to follow the Pokegama guide curve on the recession. This is due to the fact that discharges from Pokegama increase the backwater from the Mississippi River in Sandy's tailwater, which further restricts the outflow. If the discharge from Pokegama, on the recession, is increased too soon it can delay the lowering of Sandy Lake reservoir. Sandy Reservoir typically inflicts more property damage at high water levels in comparison to Pokegama. So, in this instance, Pokegama Dam is essentially operated for flood control at Sandy.

Pokegama Lake Dam/Reservoir is able to follow the guide curve during most events.

End

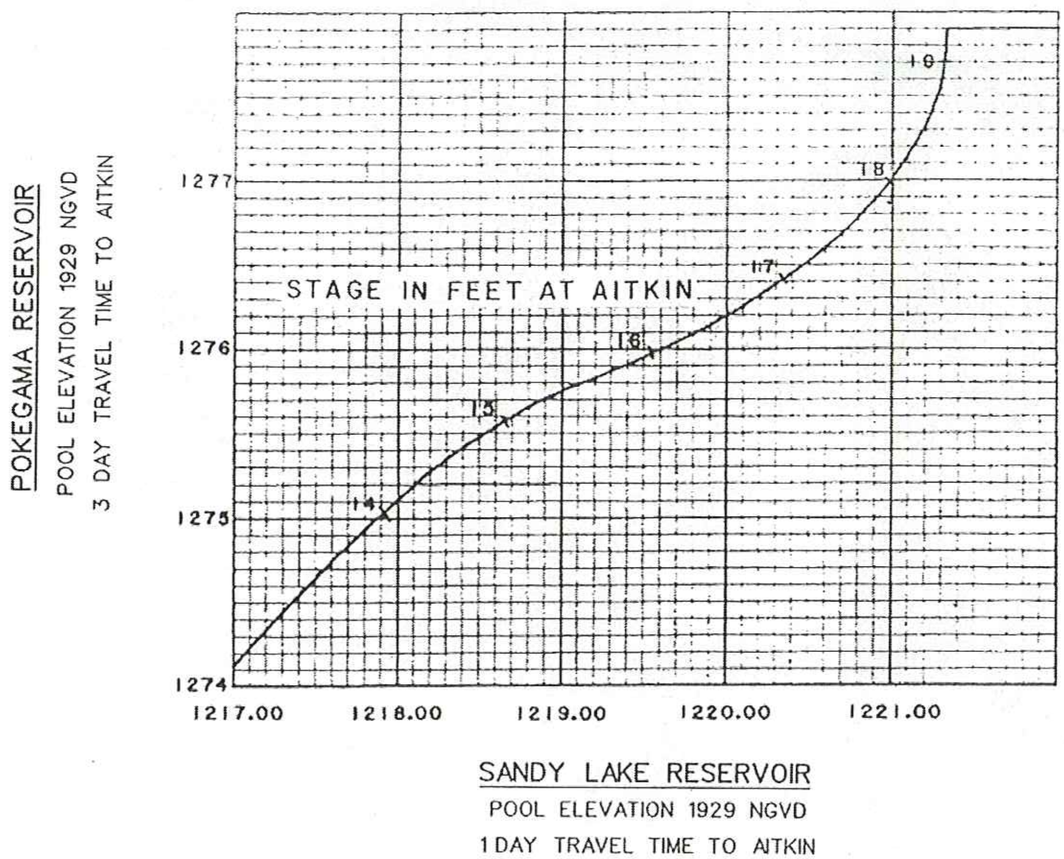
Aitkin, MN Peak Stages above approximately 12 feet, Period of Record thru 2005

Submerged time frames were obtained from graphs and are approx.

How often can Sandy Lake Dam follow the the Aitkin Flood Control Guide Curves?

1929 NGVD Date	USGS Gage Aitkin Stage (Feet)	Did Sandy Tailwater Submerge The Gates?	For How Long? (Approx.)
20-May-50	20.49	Yes	12 weeks
29-Apr-48	18.77	Yes	11 weeks
3-May-75	17.91	Yes	For ~3 weeks prior to the peak, only 1 to 2 ft of head for ~4 more weeks
28-Apr-01	17.74	Yes	For ~2 weeks prior to the peak, only 0.5 to 1 ft of head for ~9 more weeks
15-Apr-52	17.73	Yes	For ~1 week prior to the peak, only ~2 ft of head for ~4 more weeks
6-May-54	17.73	Yes	For ~4 weeks prior to the peak, only 1 to 2 ft of head for ~4 more weeks
26-Mar-45	17.51	Yes	For ~2 weeks prior to the peak, only 1 to 2 ft of head for ~4 more weeks
26-Apr-65	17.50	Yes	For ~2 weeks prior to the peak, only 0.5 to 2 ft of head for ~8 more weeks
23-Apr-69	17.32	Yes	For ~2 weeks prior to the peak, only 1 to 2 ft of head for ~4 more weeks
29-Apr-79	17.05	Yes	For ~2 weeks prior to the peak, only 0.5 to 1 ft of head for ~4 more weeks
15-Apr-47	16.60	Borderline	Only ~1 ft of head for ~4 weeks after the peak, very little control
29-Apr-66	16.60	Yes	For ~6 weeks prior to the peak, minimal head for ~4 more weeks
16-Apr-97	16.26	Yes	For ~2 weeks prior to the peak, ~0 to 1 ft of head for ~4 more weeks
8-May-51	16.23	Borderline	Minimal head before the peak, ~ 2 weeks
24-Apr-82	16.02	Yes	For ~1 week prior to the peak, ~ < 1 ft of head for ~4 more weeks
23-Apr-71	15.91	Yes	For ~2 weeks prior to the peak, ~ < 1 ft of head for 2 to 3 more weeks
1-May-96	15.79	Yes	For ~1 week prior to the peak, ~ < 1 ft of head for 2 to 3 more weeks
16-May-86	15.05	Yes	~1 to 2 foot of head for ~8 weeks during the entire event, very little control
24-Apr-72	14.72	Yes	For ~1 week prior to the peak, ~ < 1 ft of head for 2 to 3 more weeks
25-Apr-74	14.62	Yes	For ~1 week prior to the peak, ~ < 1 ft of head for ~8 more weeks
2-May-85	13.90	Borderline	Minimal head for ~ 6 weeks
28-Apr-57	13.82	Yes	For ~1 week prior to the peak, ~ < 1 ft of head for ~2 more weeks
13-May-64	13.78	Borderline	Minimal head for ~ 2 weeks
31-May-62	13.65	Borderline	Minimal head for ~ 4 weeks
3-May-70	13.42	Yes	For ~1 week prior to the peak, ~ < 1 ft of head for ~3 more weeks
23-Apr-89	13.30	Yes	For ~2 weeks prior to the peak, ~ very little head for ~2 more weeks
6-May-60	13.13	Borderline	Minimal head for ~ 3 weeks
14-Apr-05	13.10	Yes	For ~1 week prior to the peak, ~ < 1 ft of head for ~2 more weeks
11-Apr-67	13.07	Yes	For ~2 weeks prior to the peak, ~ very little head for ~3 more weeks
2-May-94	12.67	Borderline	Minimal head for ~ 3 weeks
5-Apr-63	12.37	Borderline	Minimal head for ~ 1 week
11-Jul-02	12.27	Borderline	Minimal head for ~ 1 week

GUIDE CURVE FOR SPRING FLOOD, APPROXIMATELY MARCH - 15 MAY



NOTES:

1. THE SPRING AND SUMMER GUIDE CURVES WERE DEVELOPED FROM AN ANALYSIS OF 14 FLOOD EVENTS AT AITKIN WHEN THE RIVER EXCEEDED A 17-FOOT STAGE. THE ANALYSIS, THEREFORE, IS BASED ON A CERTAIN AMOUNT OF HINDSIGHT. ACTUAL OPERATIONS IN ANY PARTICULAR YEAR MAY RESULT IN THE USE OF MORE OR LESS RESERVOIR STORAGE THAN INDICATED BY THE CURVE TO EFFECT STAGE REDUCTIONS AT AITKIN. THE CURVES SHOULD BE FOLLOWED AS CLOSELY AS POSSIBLE. THE RELATIONSHIP IS ALSO AFFECTED BY THE AREAL DISTRIBUTION AND TIME-VOLUME RELATIONSHIPS OF INDIVIDUAL FLOODS AS WELL AS THE ACCURACY OF FLOOD FORECASTS.

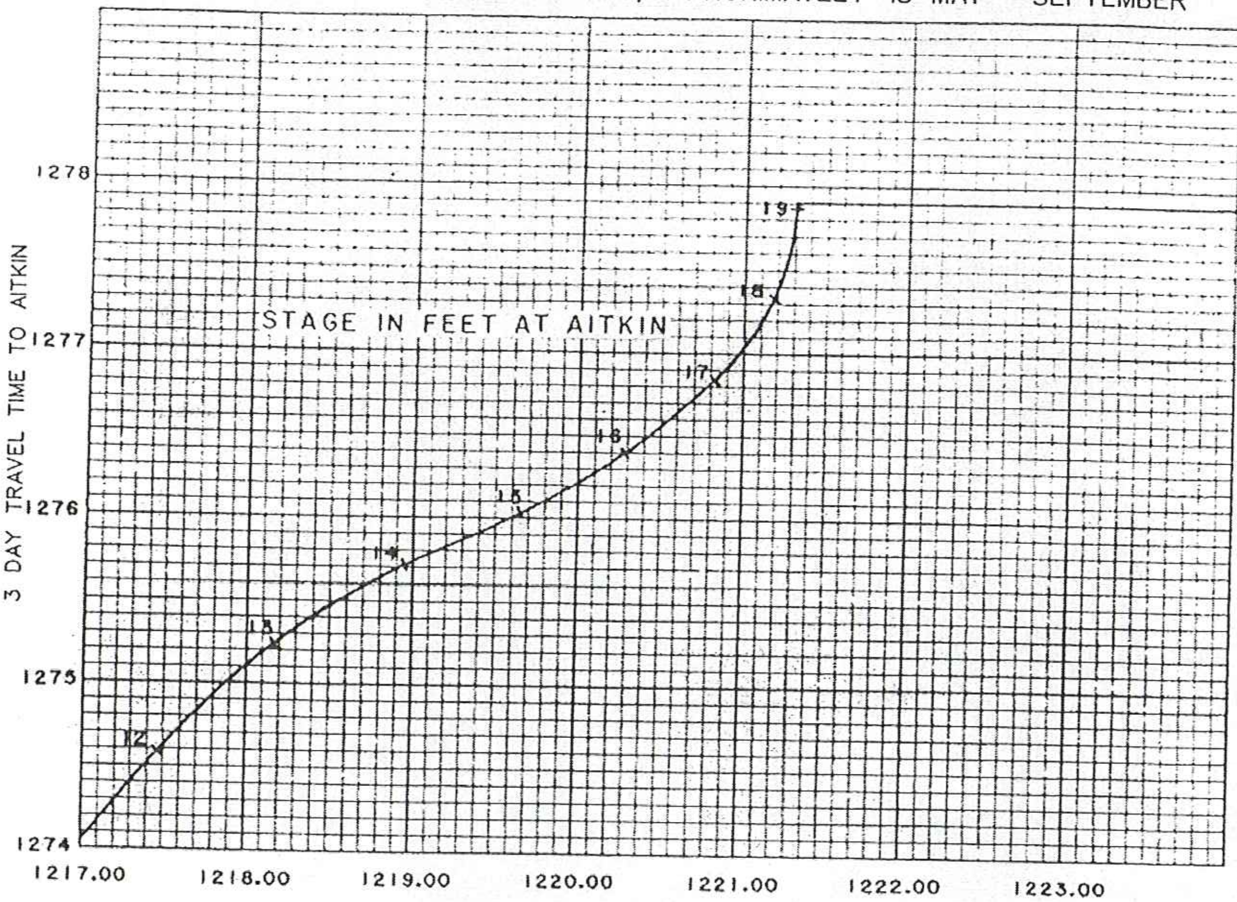
2. THE CURVE SHOWS THE RELATION BETWEEN MAXIMUM RESERVOIR ELEVATION AND CORRESPONDING PEAK FLOOD STAGE ON THE MISSISSIPPI RIVER AT AITKIN WHICH WILL RESULT (ON THE AVERAGE) IN THE MINIMUM TOTAL FLOOD DAMAGES TO AFFECTED INTERESTS IN THE THREE PRINCIPAL DAMAGE AREAS.

1 DAY TRAVEL TIME TO AITKIN FROM SANDY LAKE
3 DAY TRAVEL TIME TO AITKIN FROM POKEGAMA RESERVOIR

AITKIN GAGE ZERO - 1182.41
POKEGAMA GAGE ZERO - 1264.42
SANDY GAGE ZERO - 1207.31

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 3, POKEGAMA LAKE
SANDY LAKE & POKEGAMA RESERVOIRS
GUIDE CURVE FOR SPRING FLOODS
APPROXIMATELY MARCH - 15 MAY
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

GUIDE CURVE FOR SUMMER FLOOD, APPROXIMATELY 15 MAY - SEPTEMBER



SANDY LAKE RESERVOIR
POOL ELEVATION 1929 NGVD
1 DAY TRAVEL TIME TO AITKIN

NOTES:

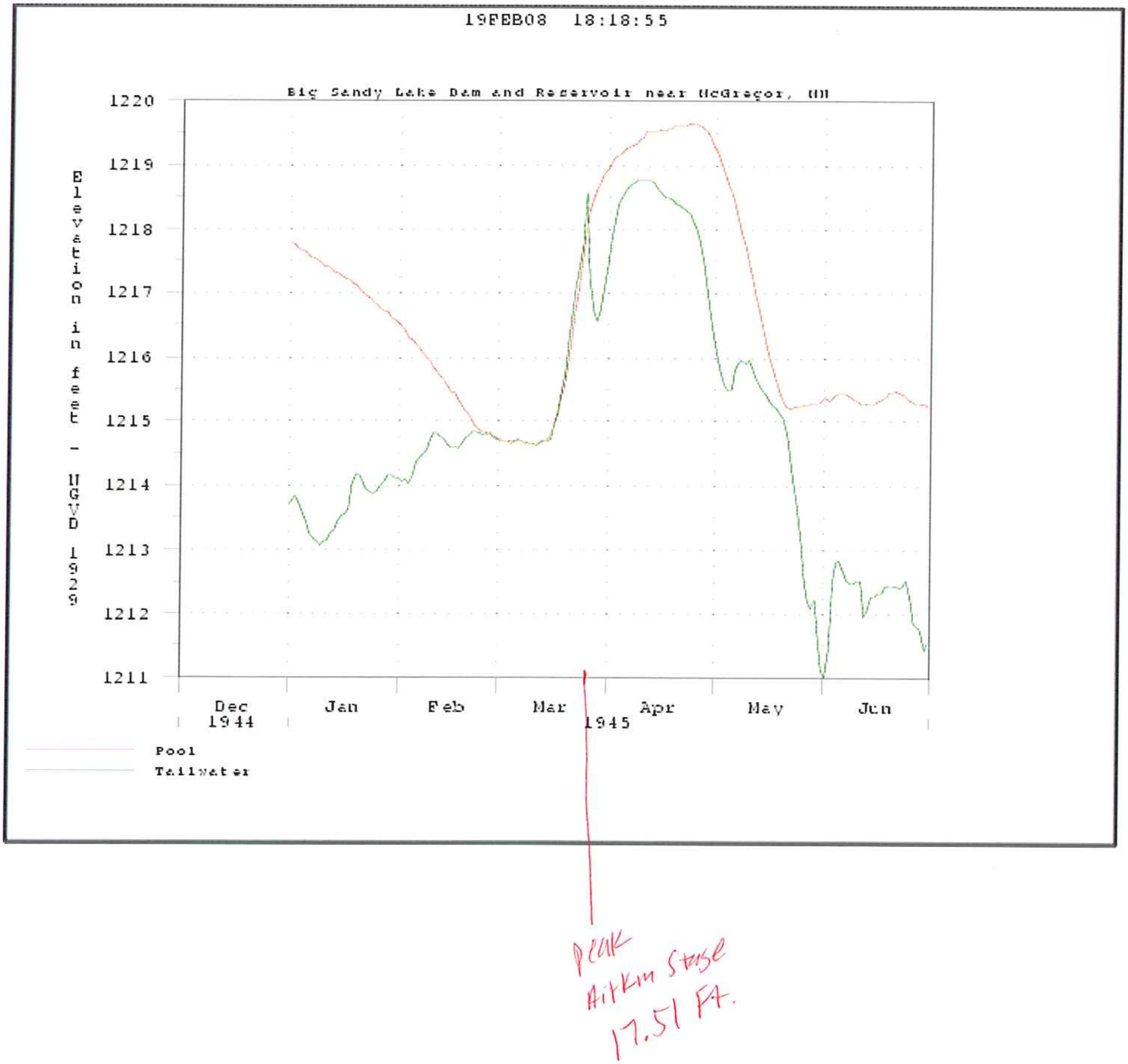
1. THE SPRING AND SUMMER GUIDE CURVES WERE DEVELOPED FROM AN ANALYSIS OF 14 FLOOD EVENTS AT AITKIN WHEN THE RIVER EXCEEDED A 17-FOOT STAGE. THE ANALYSIS, THEREFORE, IS BASED ON A CERTAIN AMOUNT OF HINDSIGHT. ACTUAL OPERATIONS IN ANY PARTICULAR YEAR MAY RESULT IN THE USE OF MORE OR LESS RESERVOIR STORAGE THAN INDICATED BY THE CURVE TO EFFECT STAGE REDUCTIONS AT AITKIN. THE CURVES SHOULD BE FOLLOWED AS CLOSELY AS POSSIBLE. THE RELATIONSHIP IS ALSO AFFECTED BY THE AREAL DISTRIBUTION AND TIME-VOLUME RELATIONSHIPS OF INDIVIDUAL FLOODS AS WELL AS THE ACCURACY OF FLOOD FORECASTS.

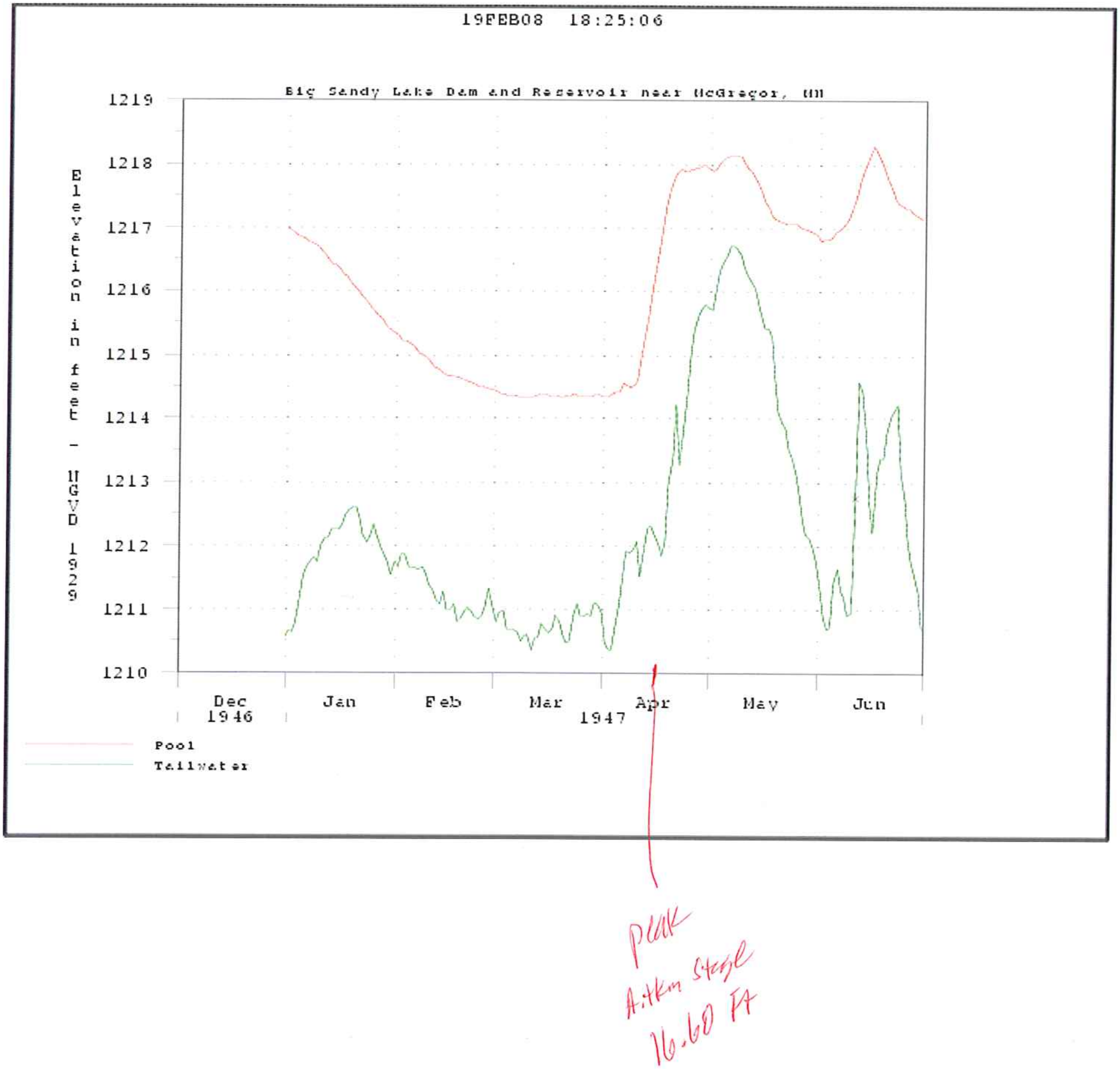
2. THE CURVE SHOWS THE RELATION BETWEEN MAXIMUM RESERVOIR ELEVATION AND CORRESPONDING PEAK FLOOD STAGE ON THE MISSISSIPPI RIVER AT AITKIN WHICH WILL RESULT (ON THE AVERAGE) IN THE MINIMUM TOTAL FLOOD DAMAGES TO AFFECTED INTERESTS IN THE THREE PRINCIPAL DAMAGE AREAS.

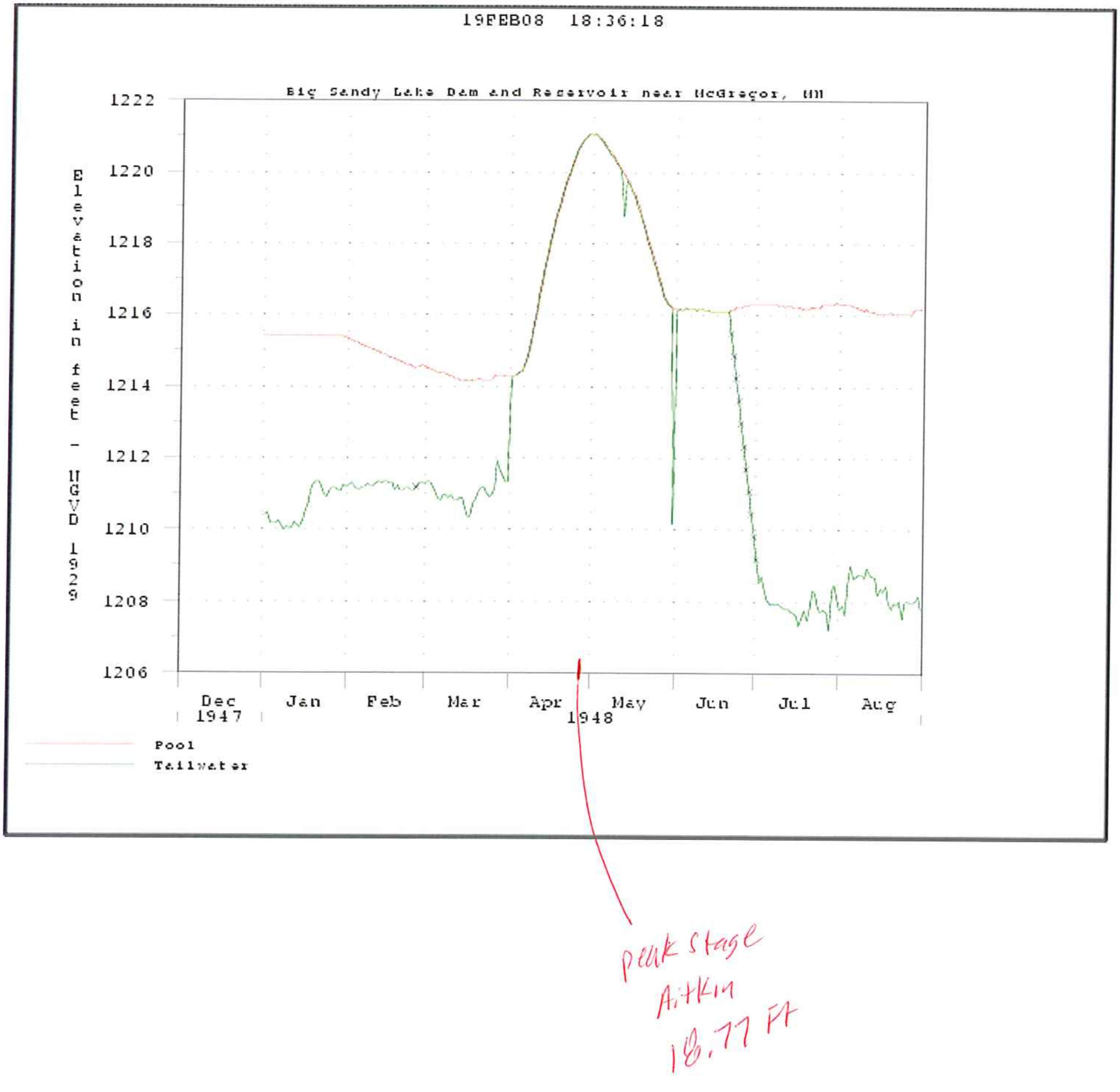
1 DAY TRAVEL TIME TO AITKIN FROM SANDY LAKE
3 DAY TRAVEL TIME TO AITKIN FROM POKEGAMA RESERVOIR

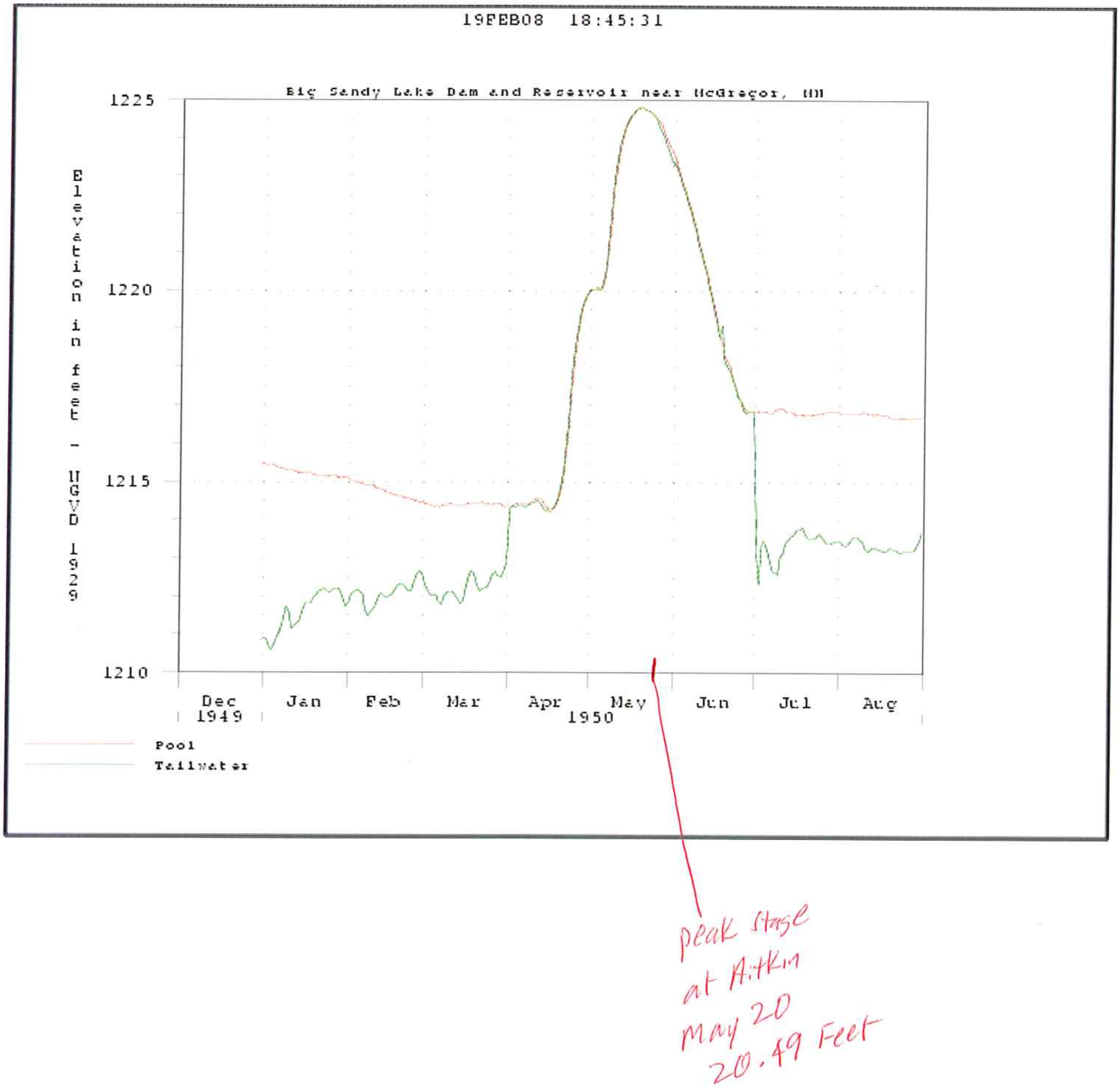
AITKIN GAGE ZERO - 1182.41
POKEGAMA GAGE ZERO - 1264.42
SANDY GAGE ZERO - 1207.31

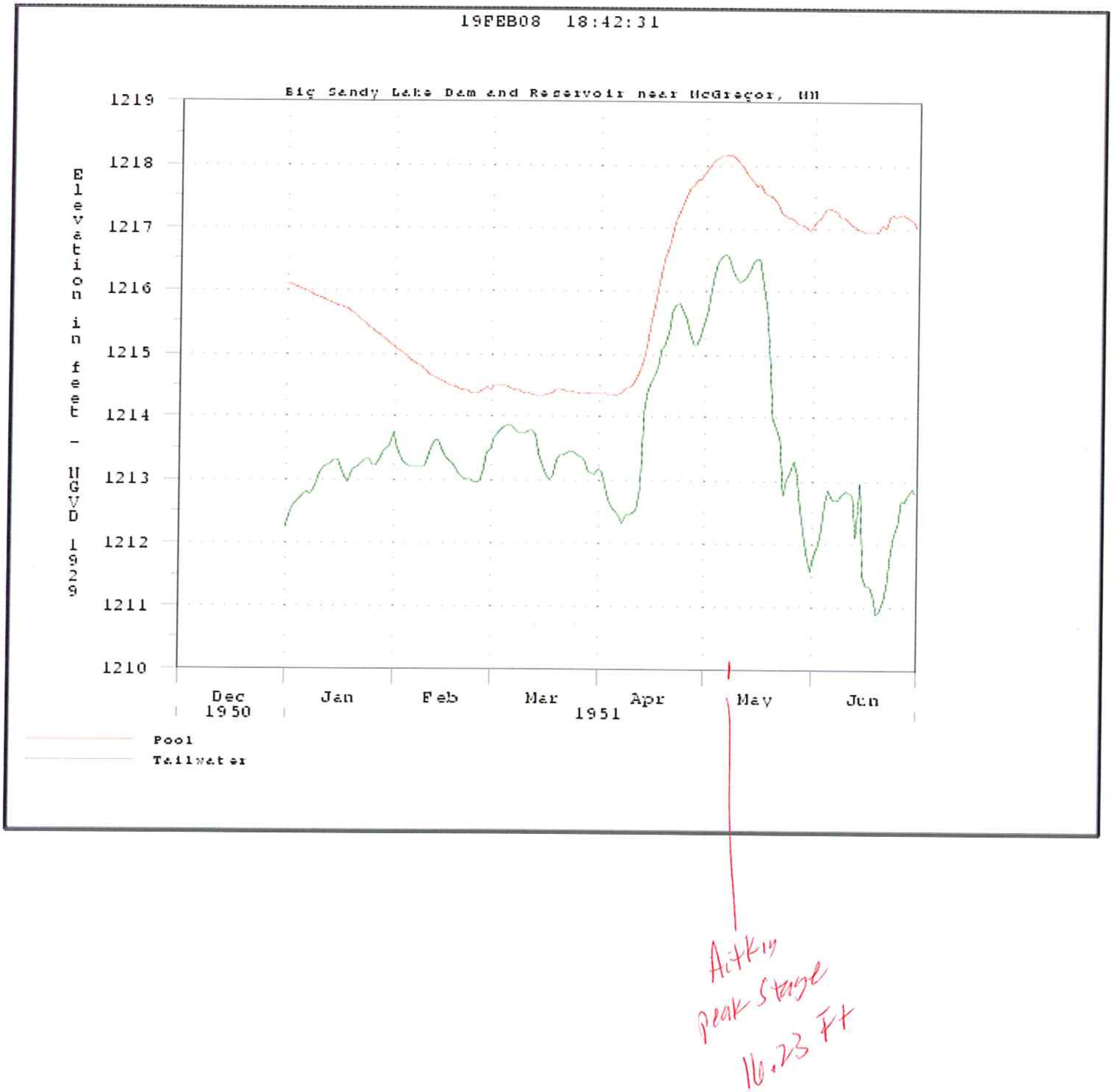
MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 3, POKEGAMA LAKE
SANDY LAKE & POKEGAMA RESERVOIRS
GUIDE CURVE FOR SUMMER FLOODS
APPROXIMATELY 15 MAY - SEPTEMBER
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

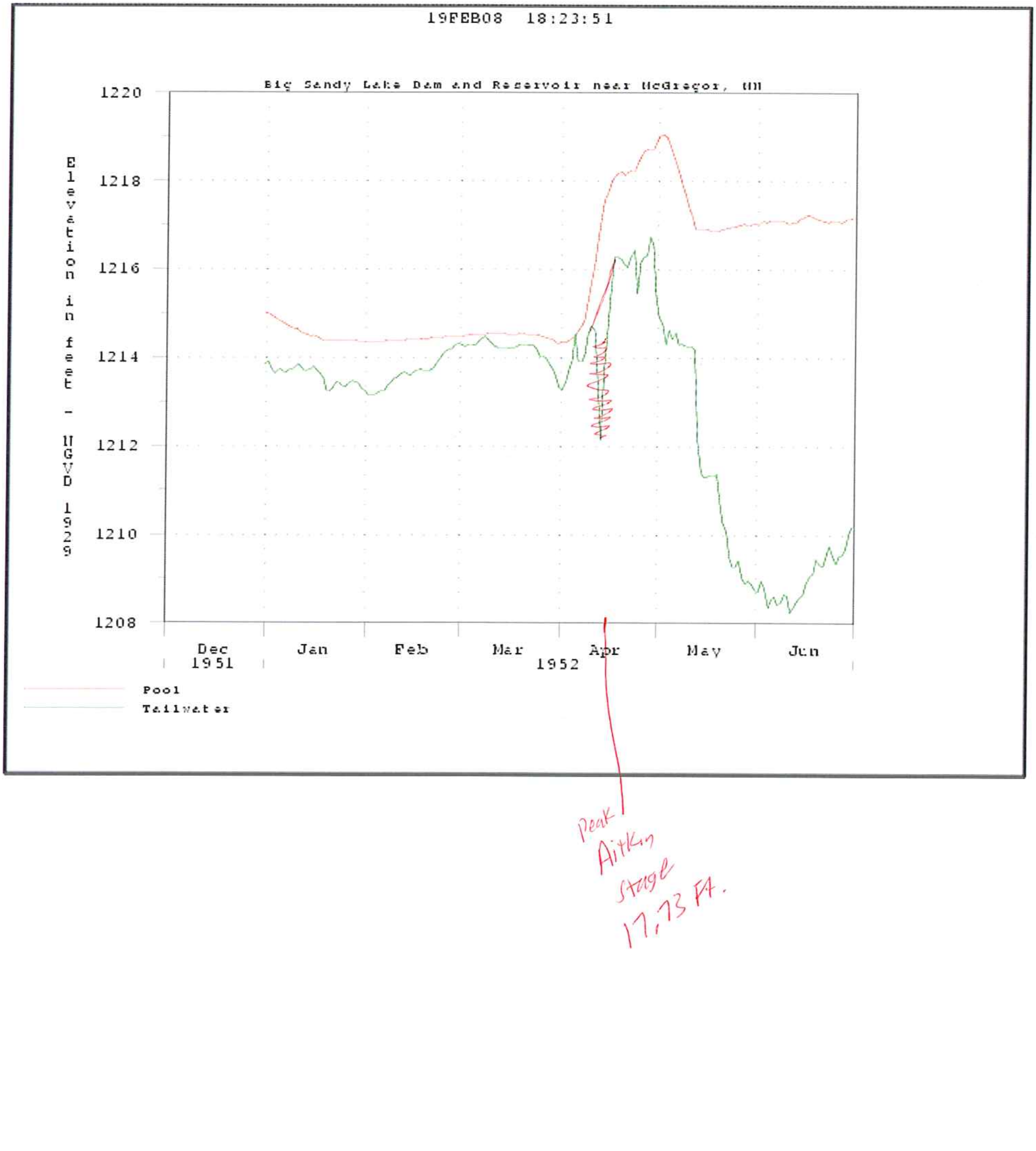

19FEB08 18:18:55
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1220
1219
1218
1217
1216
1215
1214
1213
1212
1211
Dec 1944
Jan
Feb
Mar
1945
Apr
May
Jun
Pool
Tailwater
peak
Aitkin Stage
17.51 Ft.

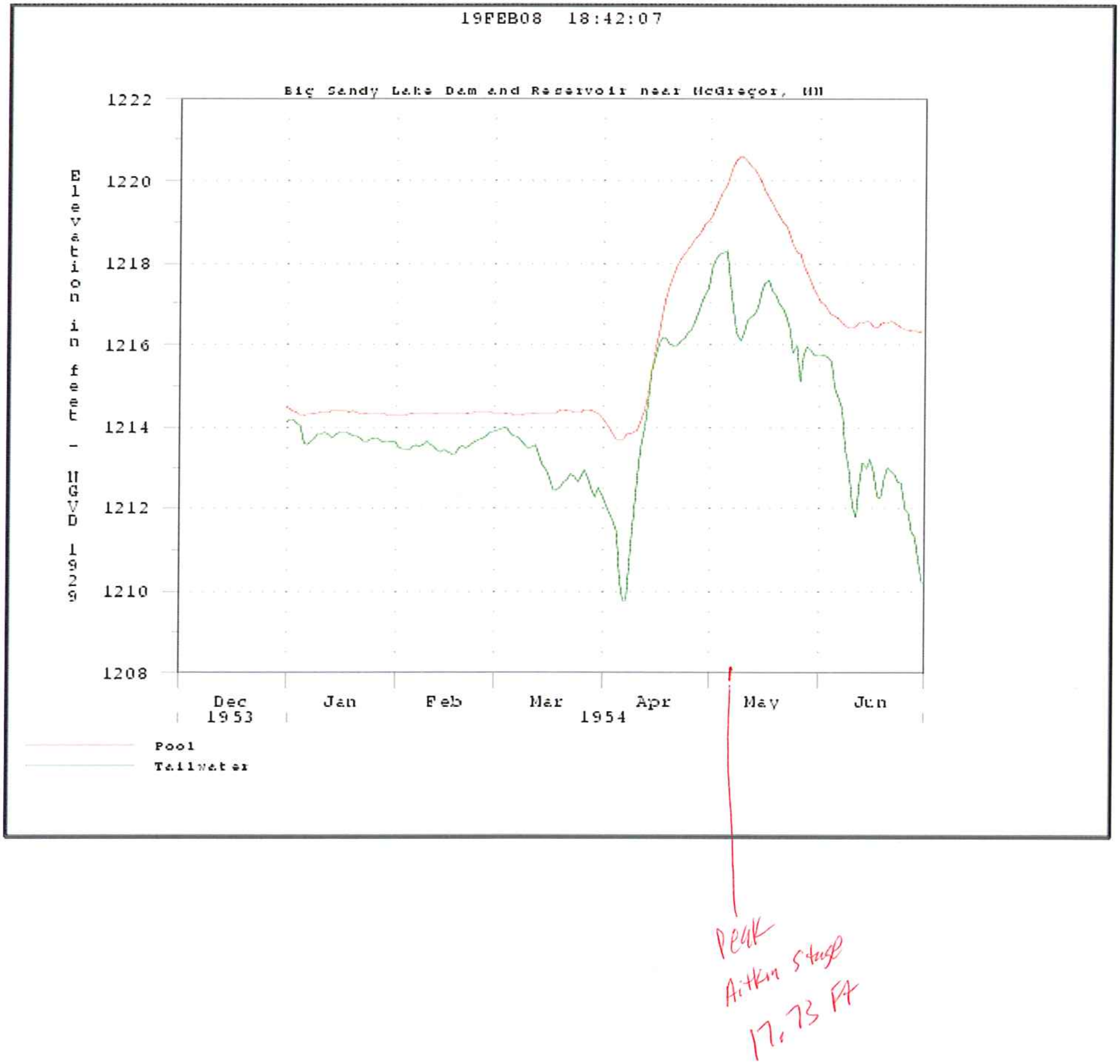

19FEB08 18:25:06
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1219
1218
1217
1216
1215
1214
1213
1212
1211
1210
Dec 1946
Jan
Feb
Mar
Apr
May
Jun
1947
Pool
Tailwater
peak
Aitkin Stage
16.60 Ft

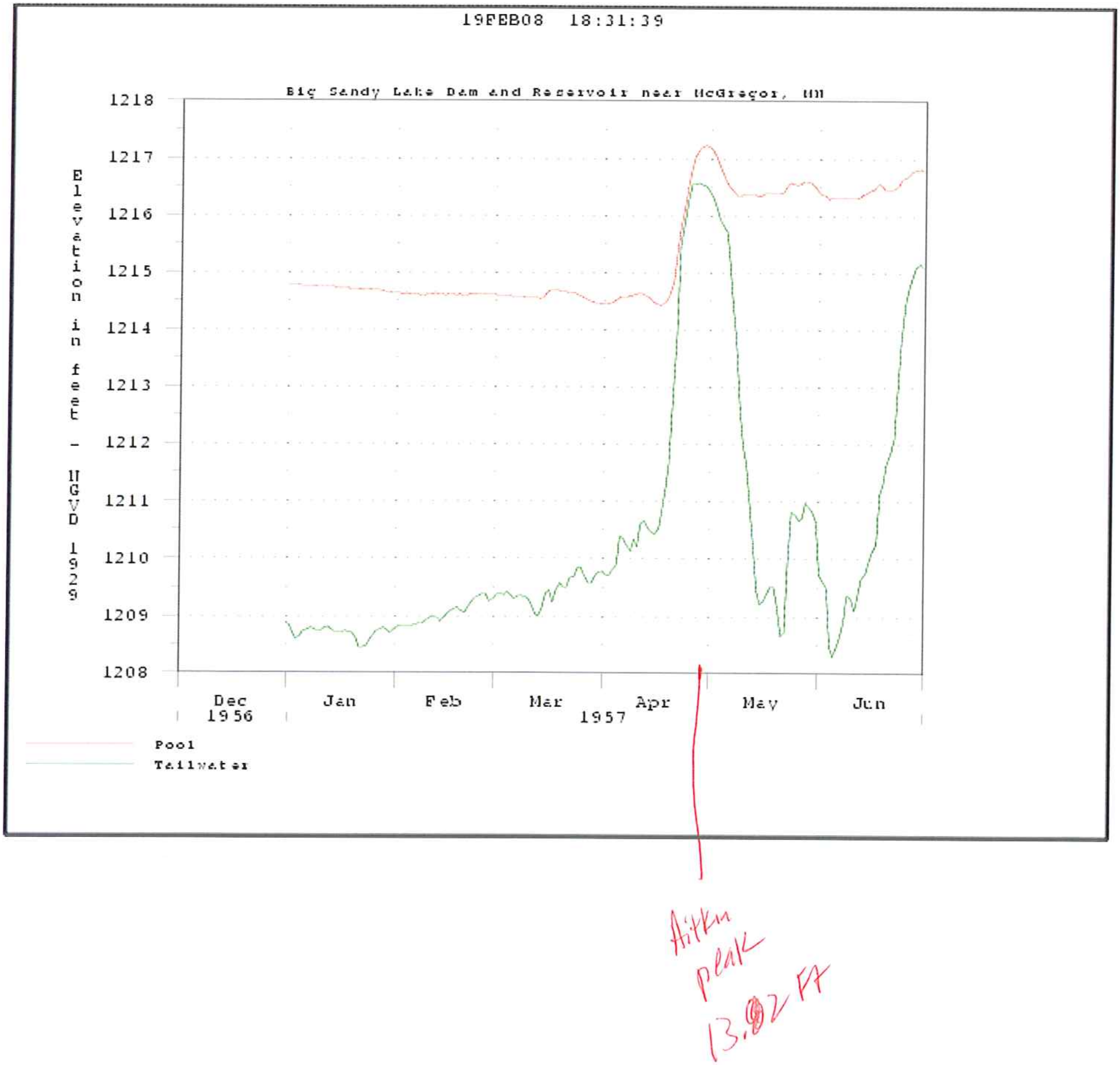

19FEB08 18:36:18
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1220
1218
1216
1214
1212
1210
1208
1206
Dec 1947
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
1948
Pool
Tailwater
peak stage
Aitkin
18.77 Ft

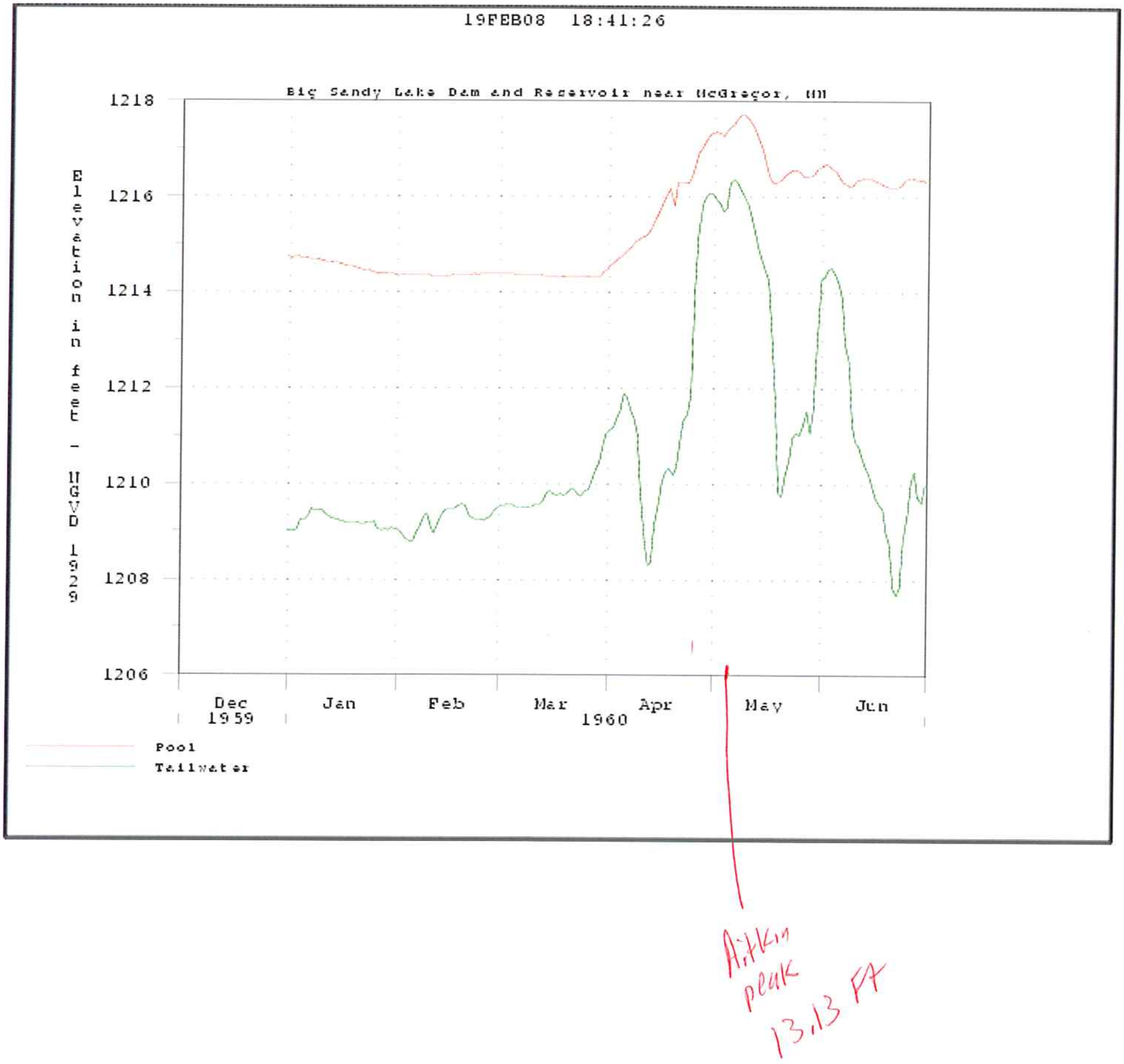

19FEB08 18:45:31
Big Sandy Lake Dam and Reservoir near McGregor, MN
1225
1220
1215
1210
Elevation in feet - NGVD 1929
Dec 1949
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
1950
Pool
Tailwater
peak stage
at Aitkin
May 20
20.49 Feet


19FEB08 18:42:31
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1219
1218
1217
1216
1215
1214
1213
1212
1211
1210
Dec 1950
Jan
Feb
Mar
1951
Apr
May
Jun
Pool
Tailwater
Aitkin peak Stage 16.23 Ft

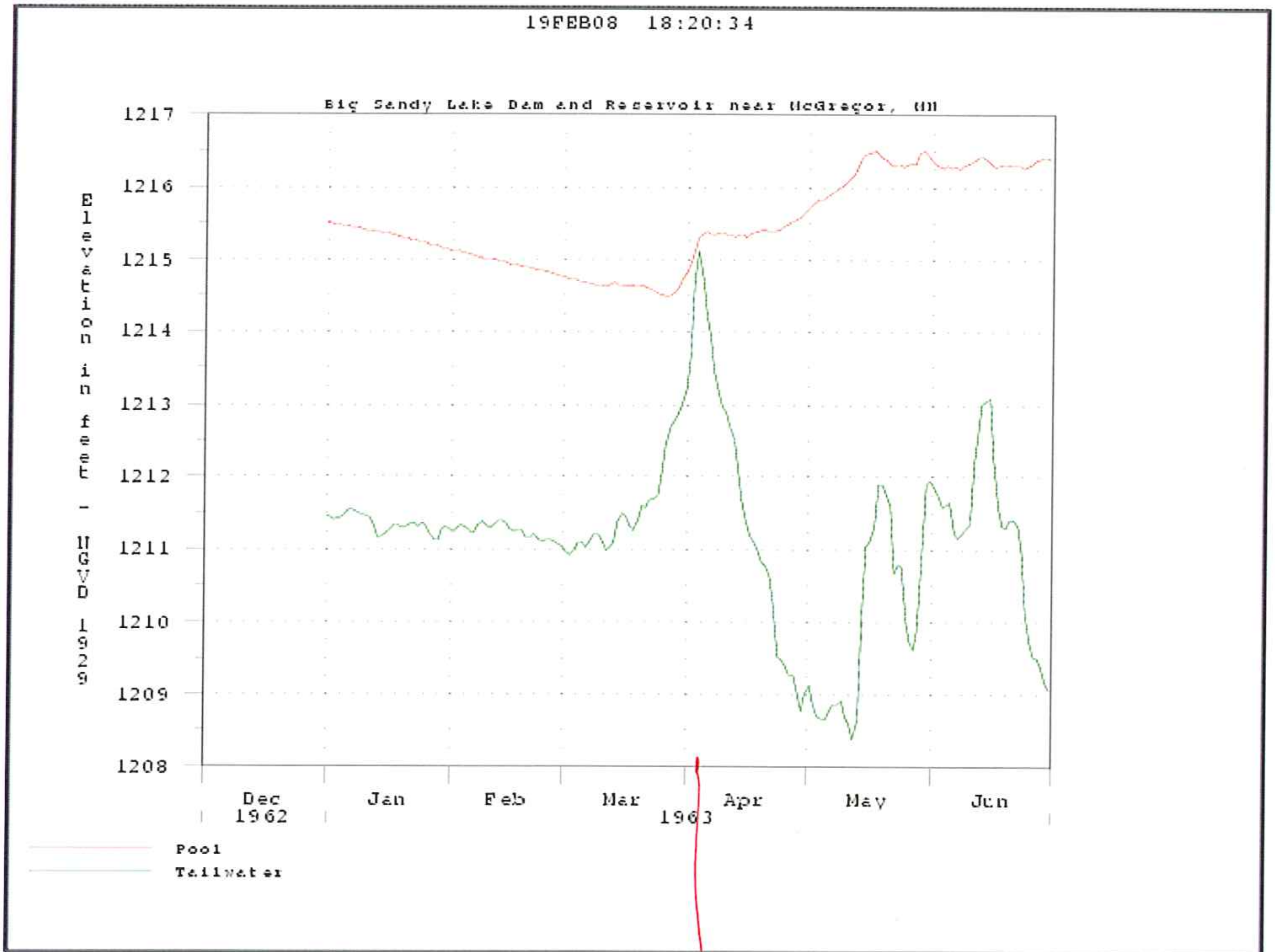

19FEB08 18:23:51
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1220
1218
1216
1214
1212
1210
1208
Dec
1951
Jan
Feb
Mar
1952
Apr
May
Jun
Pool
Tailwater
Peak Aitkin stage 17.73 Ft.


19FEB08 18:42:07
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1220
1218
1216
1214
1212
1210
1208
Dec
1953
Jan
Feb
Mar
1954
Apr
May
Jun
Pool
Tailwater
Peak
Aitkin Stage
17.73 Ft

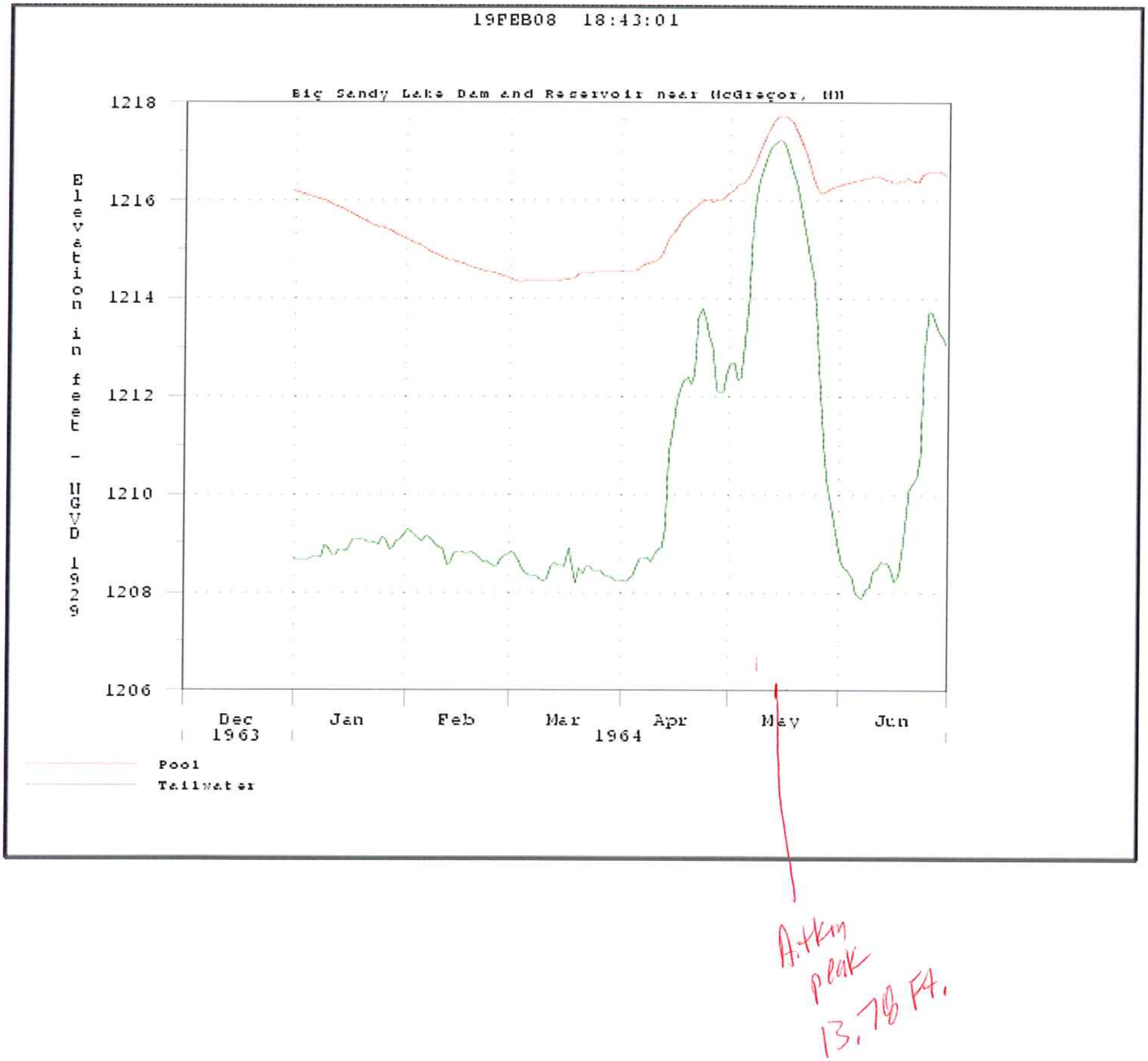

19FEB08 18:31:39
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1217
1216
1215
1214
1213
1212
1211
1210
1209
1208
Dec 1956
Jan
Feb
Mar
1957
Apr
May
Jun
Pool
Tailwater
Aitkin peak 13.02 Ft


19FEB08 18:41:26
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1216
1214
1212
1210
1208
1206
Dec 1959
Jan
Feb
Mar
1960
Apr
May
Jun
Pool
Tailwater
Aitkin peak 13.13 Ft

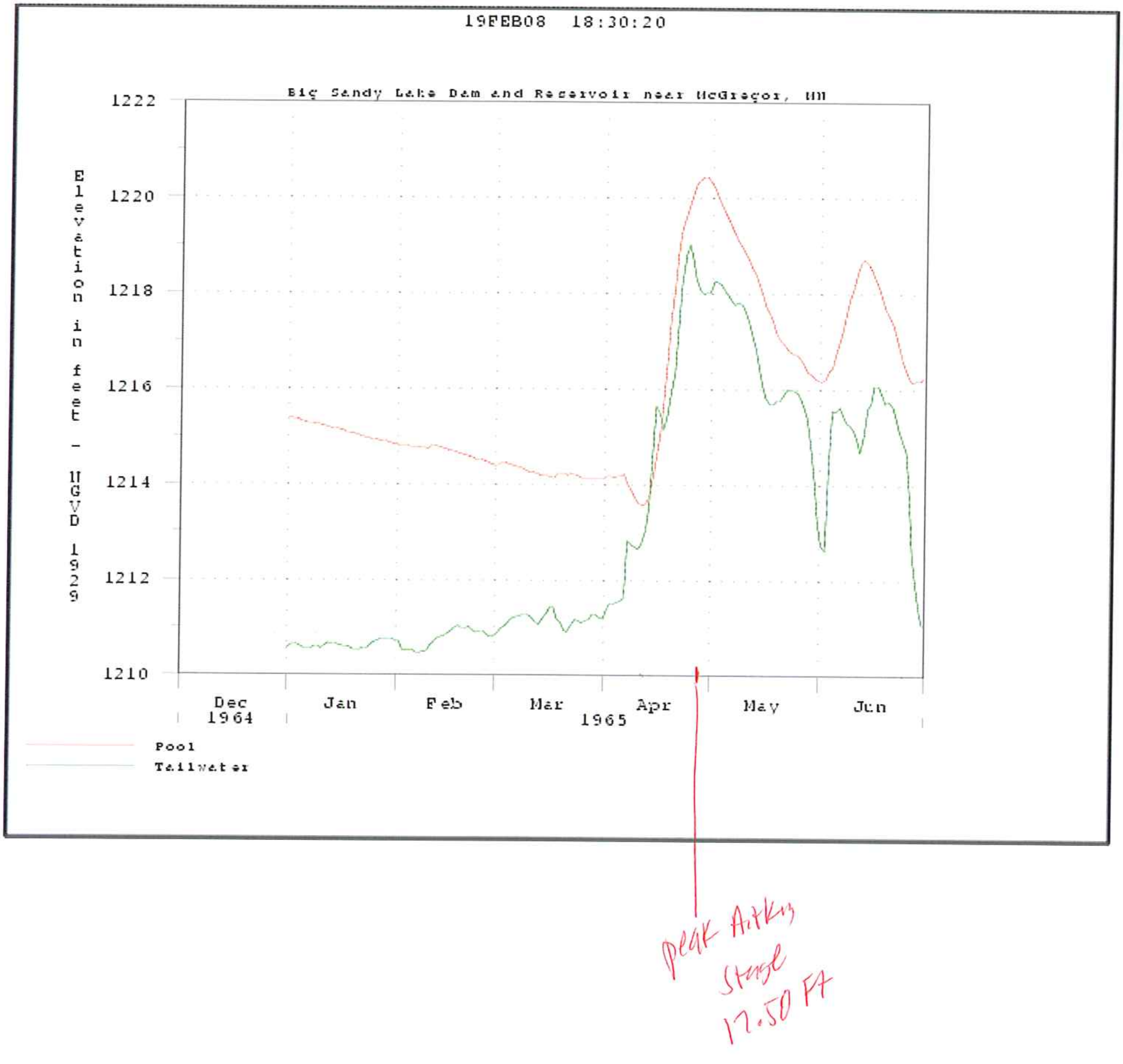
19FEB08 18:46:08
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1217
1216
1215
1214
1213
1212
1211
1210
1209
1208
Dec 1961
Jan
Feb
Mar
1962
Apr
May
Jun
Pool
Tailwater
Aitkin peak 13.65 Ft

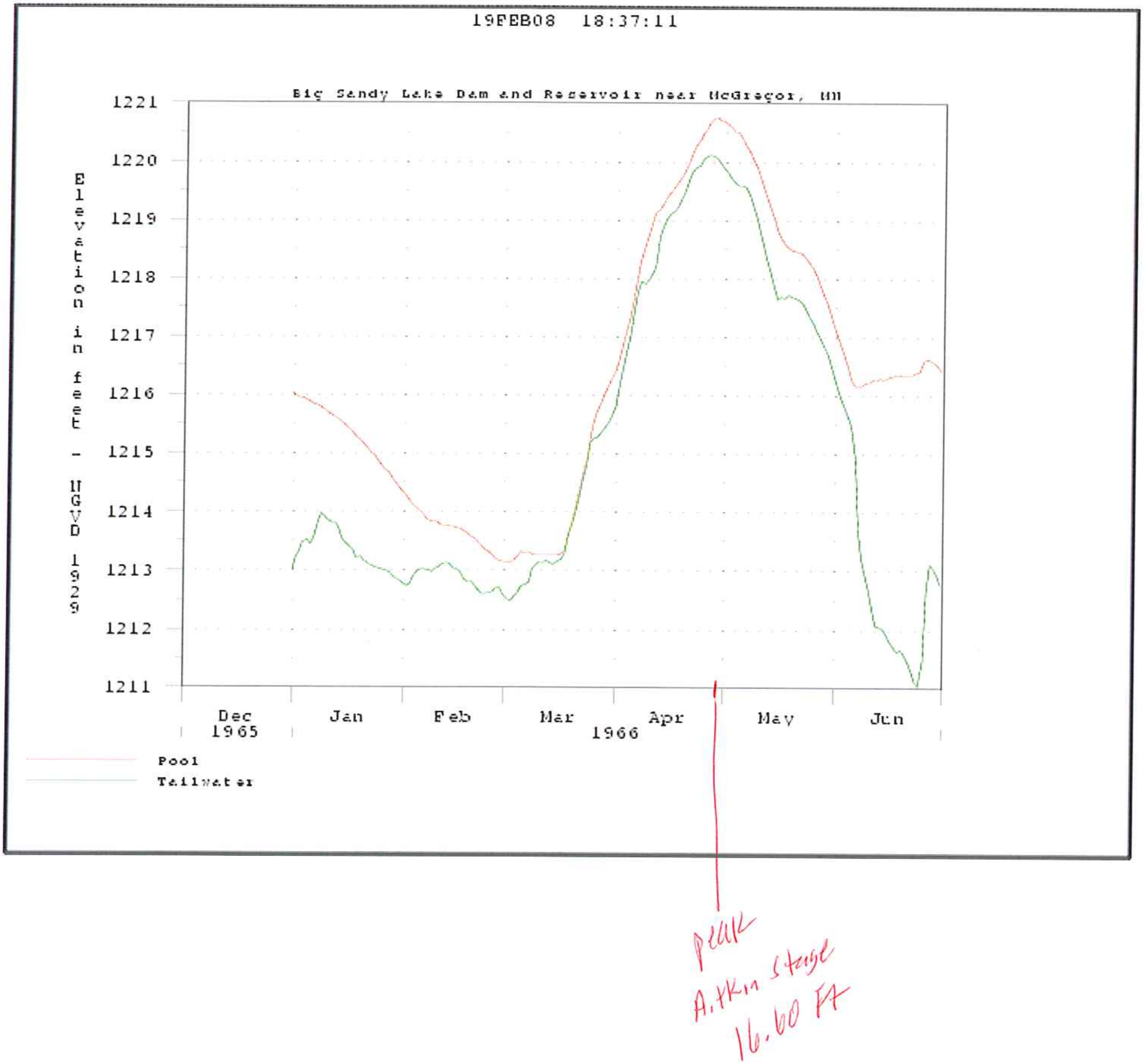


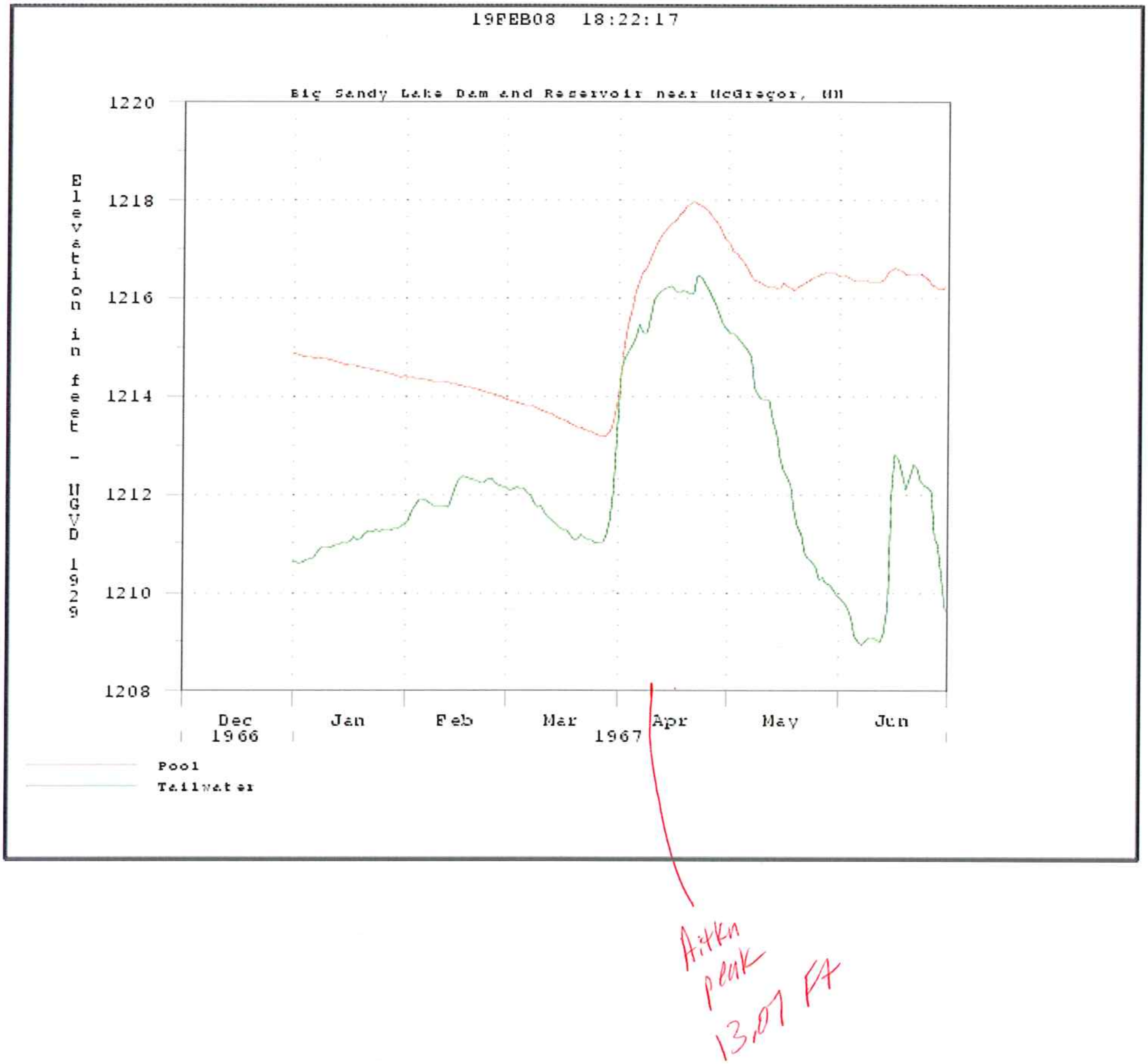
Aitkin peak 12.37 ft

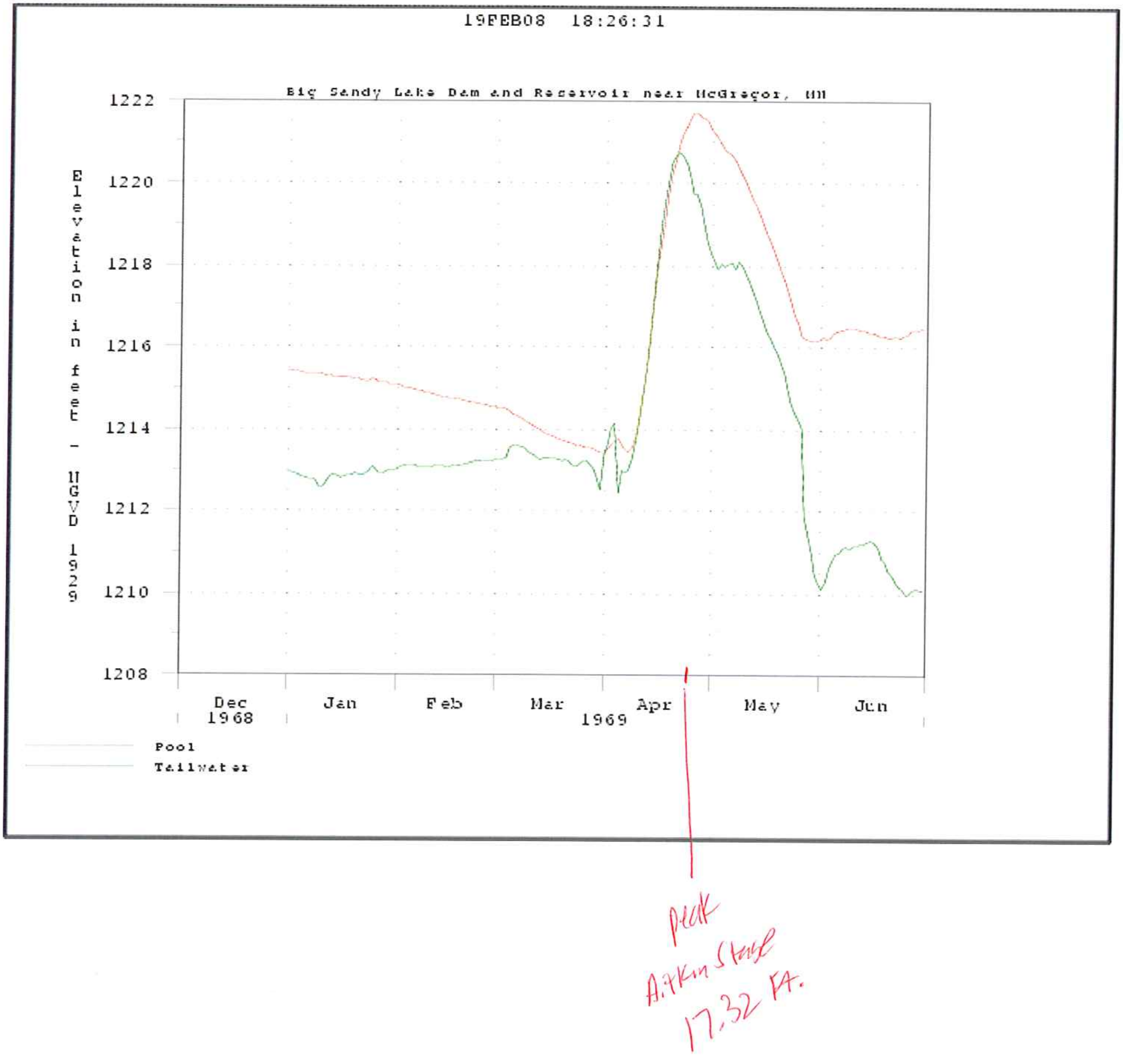


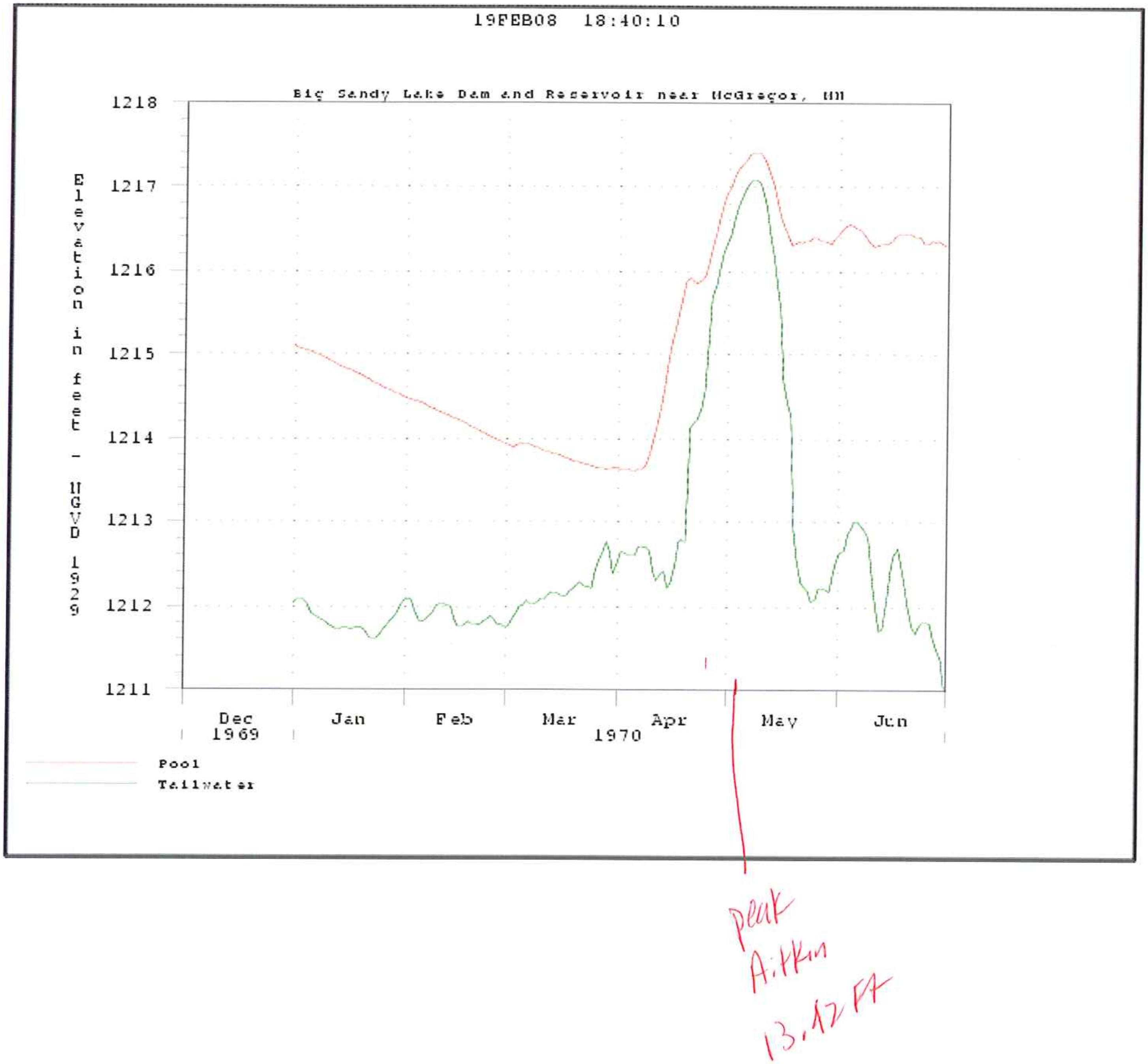
19FEB08 18:43:01
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1216
1214
1212
1210
1208
1206
Dec
1963
Jan
Feb
Mar
1964
Apr
May
Jun
Pool
Tailwater
Aitkin peak 13.78 Ft.

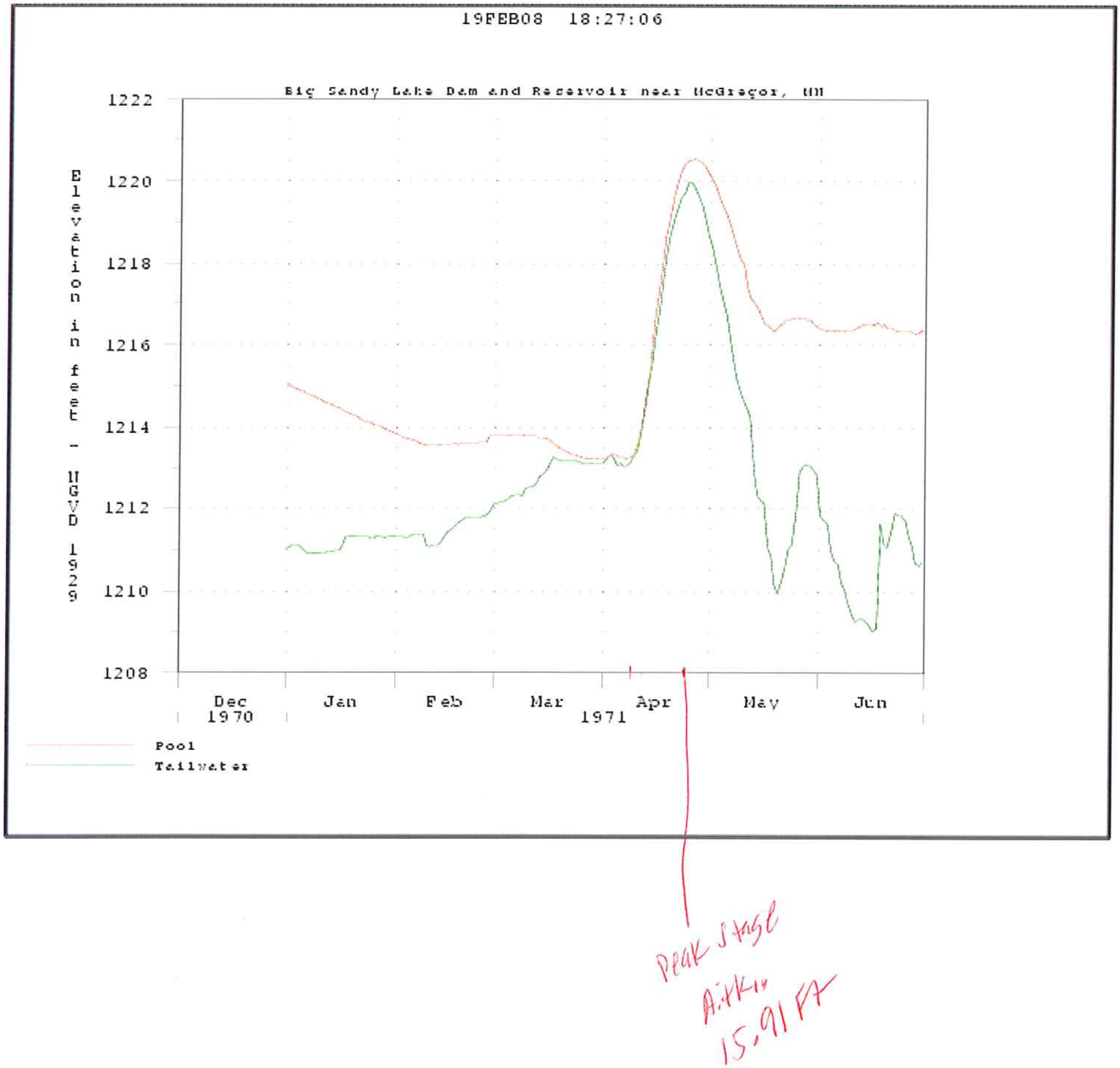

19FEB08 18:30:20
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1220
1218
1216
1214
1212
1210
Dec 1964
Jan
Feb
Mar
1965
Apr
May
Jun
Pool
Tailwater
peak Aitkin stage 17.50 Ft

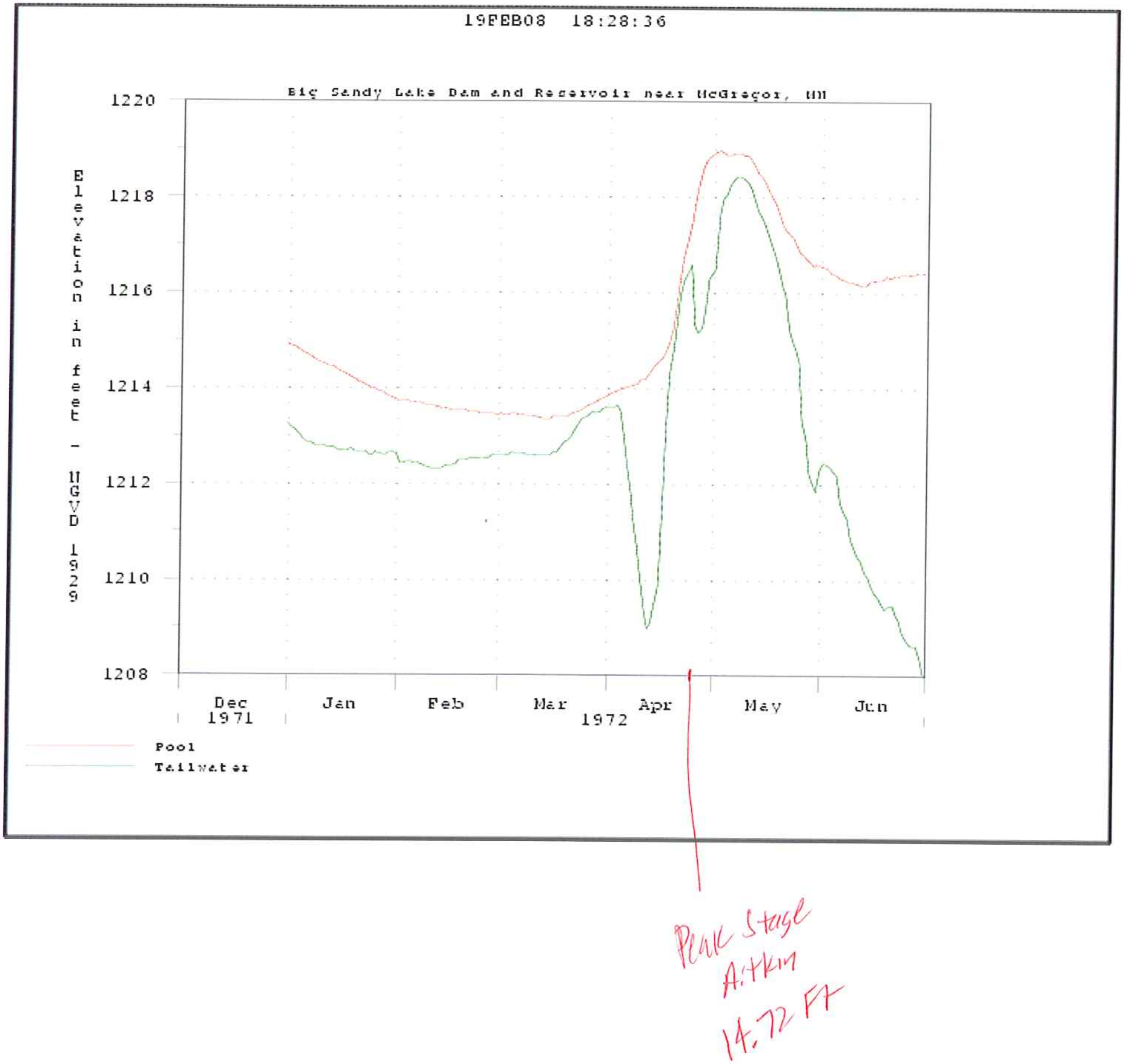

19FEB08 18:37:11
Big Sandy Lake Dam and Reservoir near McGregor, MN
1221
1220
1219
1218
1217
1216
1215
1214
1213
1212
1211
Elevation in feet - NGVD 1929
Dec 1965
Jan
Feb
Mar
1966
Apr
May
Jun
Pool
Tailwater
peak
Aitkin stage
16.60 ft

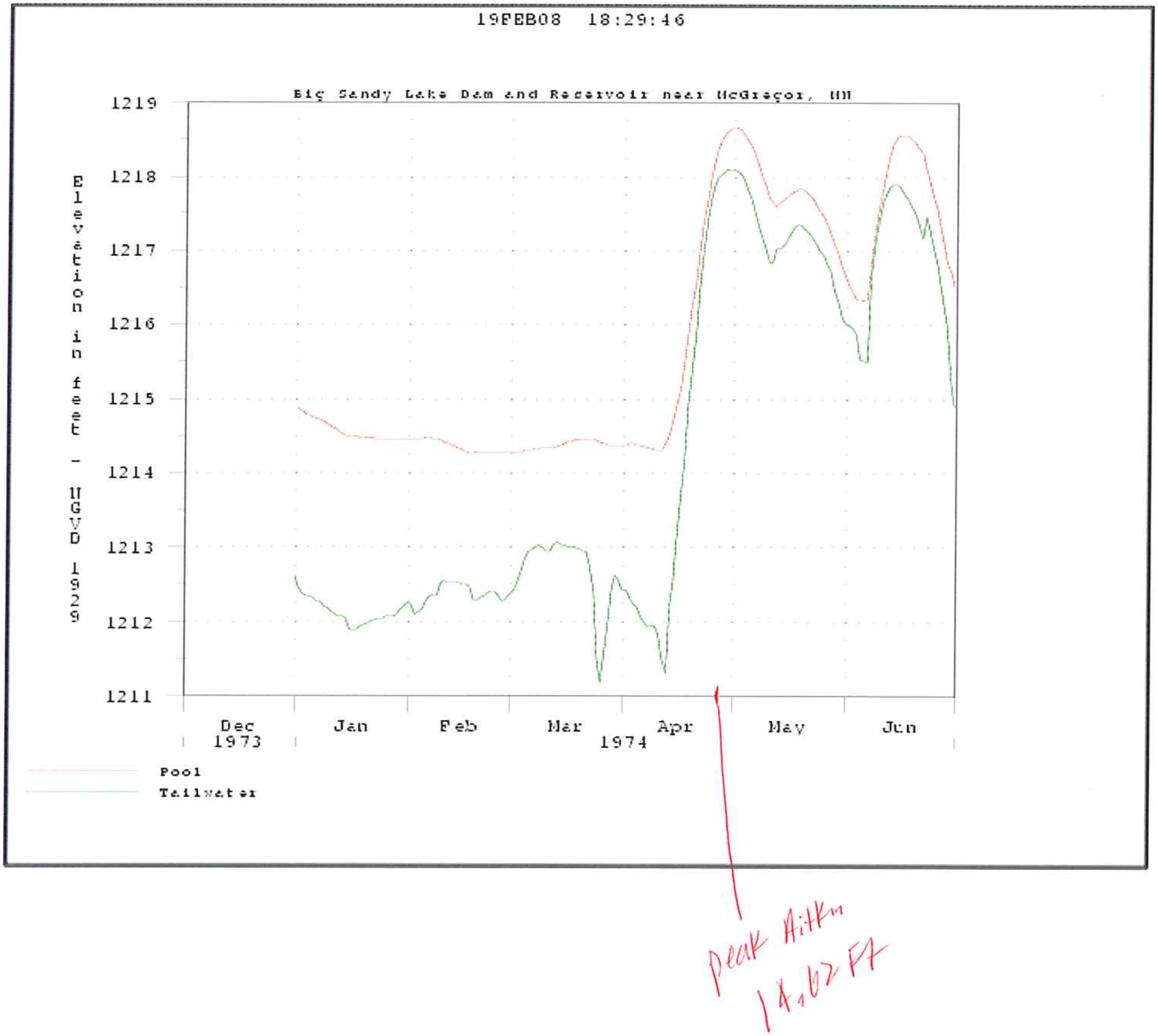

19FEB08 18:22:17
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1220
1218
1216
1214
1212
1210
1208
Dec 1966
Jan
Feb
Mar
1967
Apr
May
Jun
Pool
Tailwater
Aitkn peak 13.07 Ft


19FEB08 18:26:31
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1220
1218
1216
1214
1212
1210
1208
Dec 1968
Jan
Feb
Mar
1969
Apr
May
Jun
Pool
Tailwater
peak
Aitkin Stage
17.32 Ft.

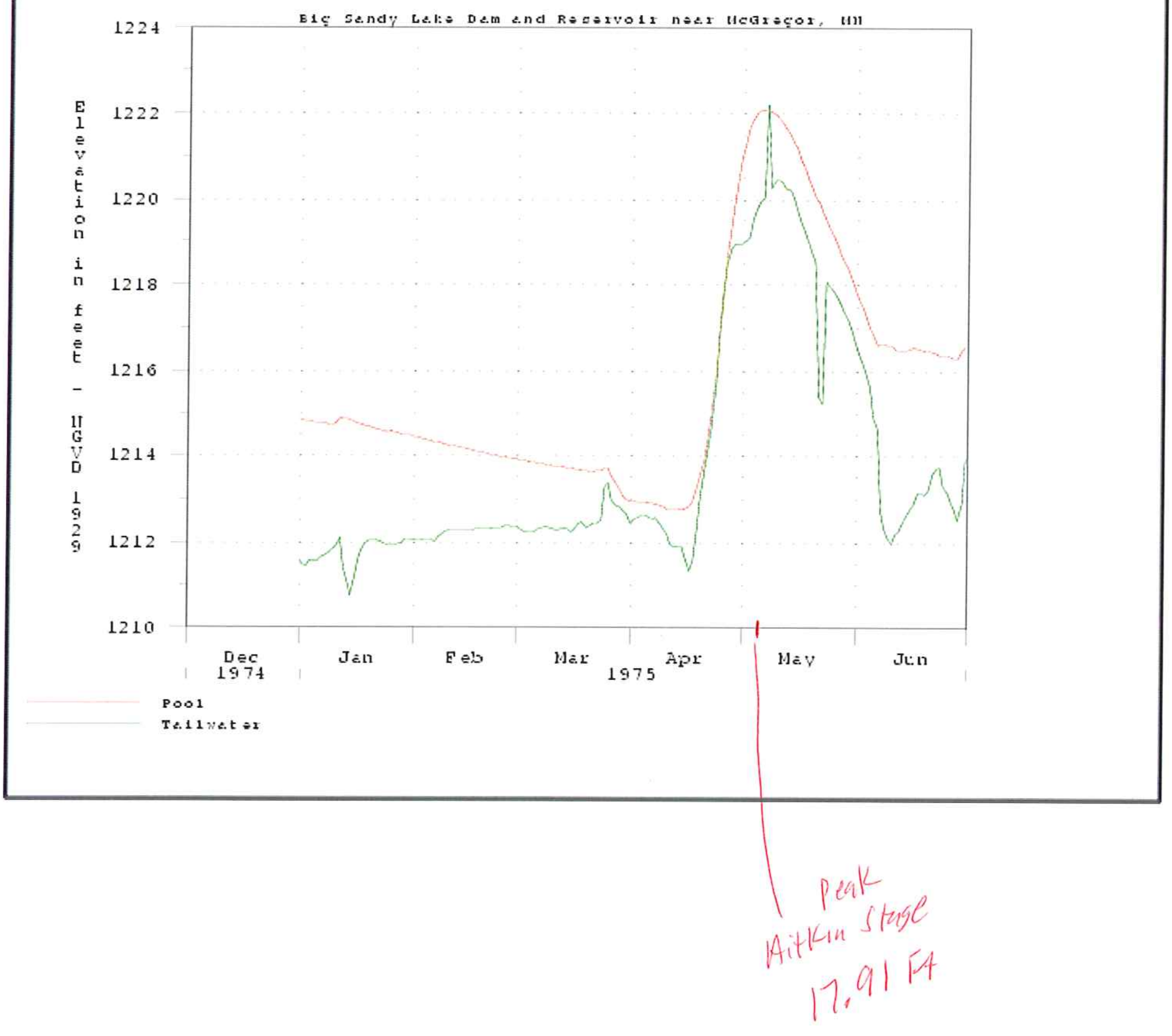

19FEB08 18:40:10
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1217
1216
1215
1214
1213
1212
1211
Dec 1969
Jan
Feb
Mar
1970
Apr
May
Jun
Pool
Tailwater
peak
Aitkin
13.12 ft

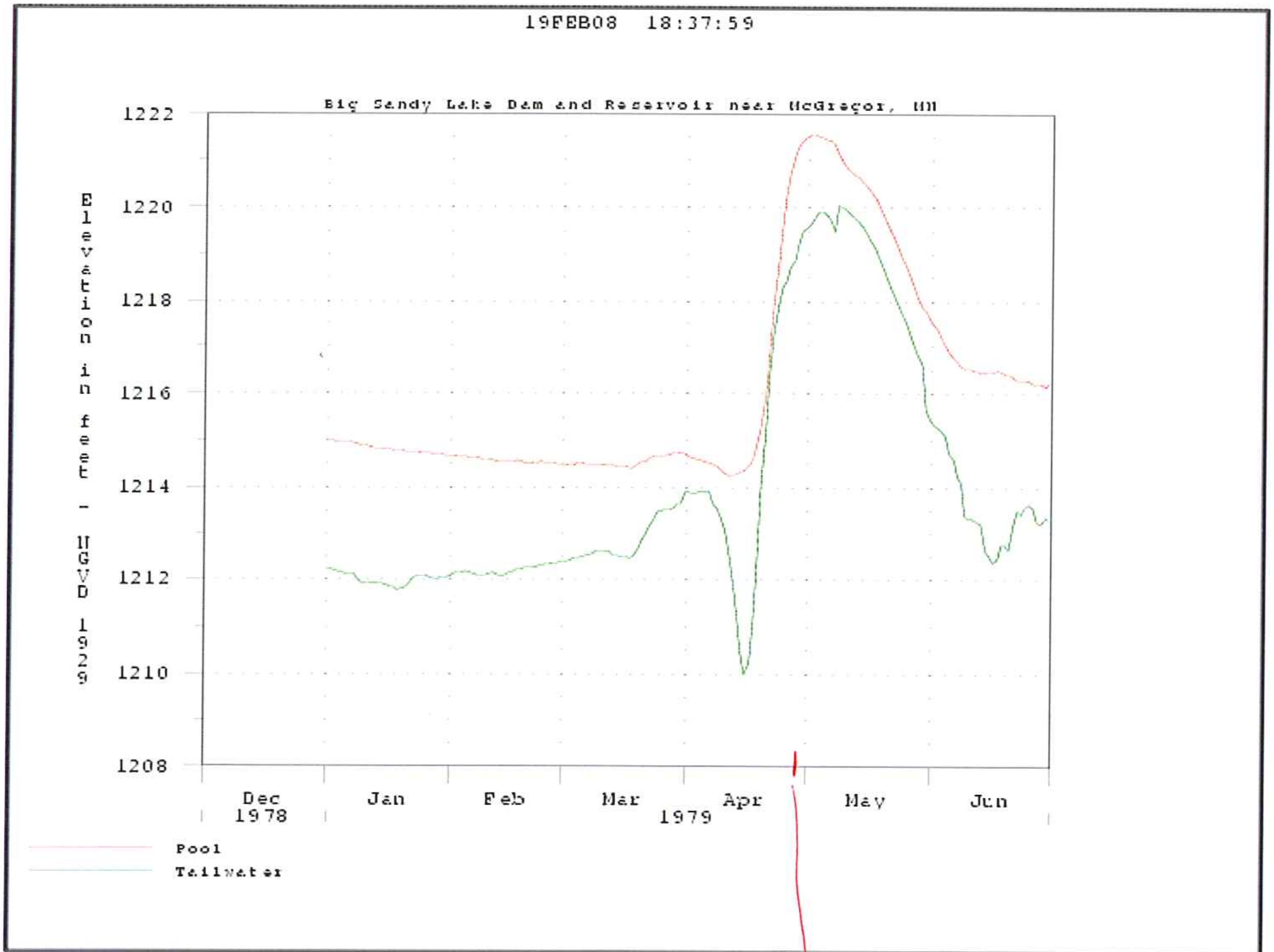

19FEB08 18:27:06
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1220
1218
1216
1214
1212
1210
1208
Dec
1970
Jan
Feb
Mar
1971
Apr
May
Jun
Pool
Tailwater
Peak Stage
Aitkin
15.91 FT


19FEB08 18:28:36
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1220
1218
1216
1214
1212
1210
1208
Dec 1971
Jan
Feb
Mar
1972
Apr
May
Jun
Pool
Tailwater
Peak Stage Aitkin 14.72 Ft

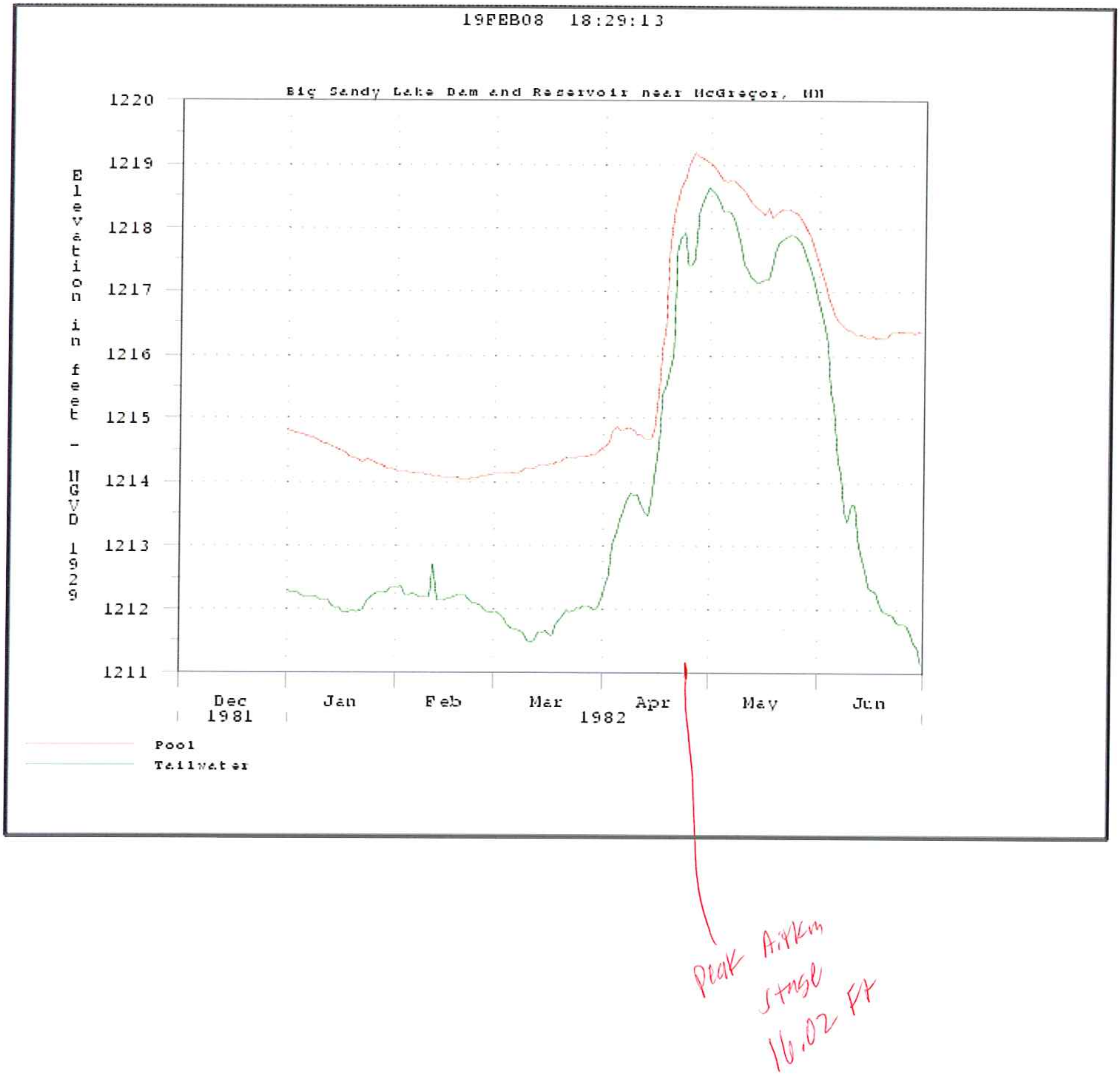

19FEB08 18:29:46
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1219
1218
1217
1216
1215
1214
1213
1212
1211
Dec
1973
Jan
Feb
Mar
1974
Apr
May
Jun
Pool
Tailwater
peak Aitkn
14.02 Ft

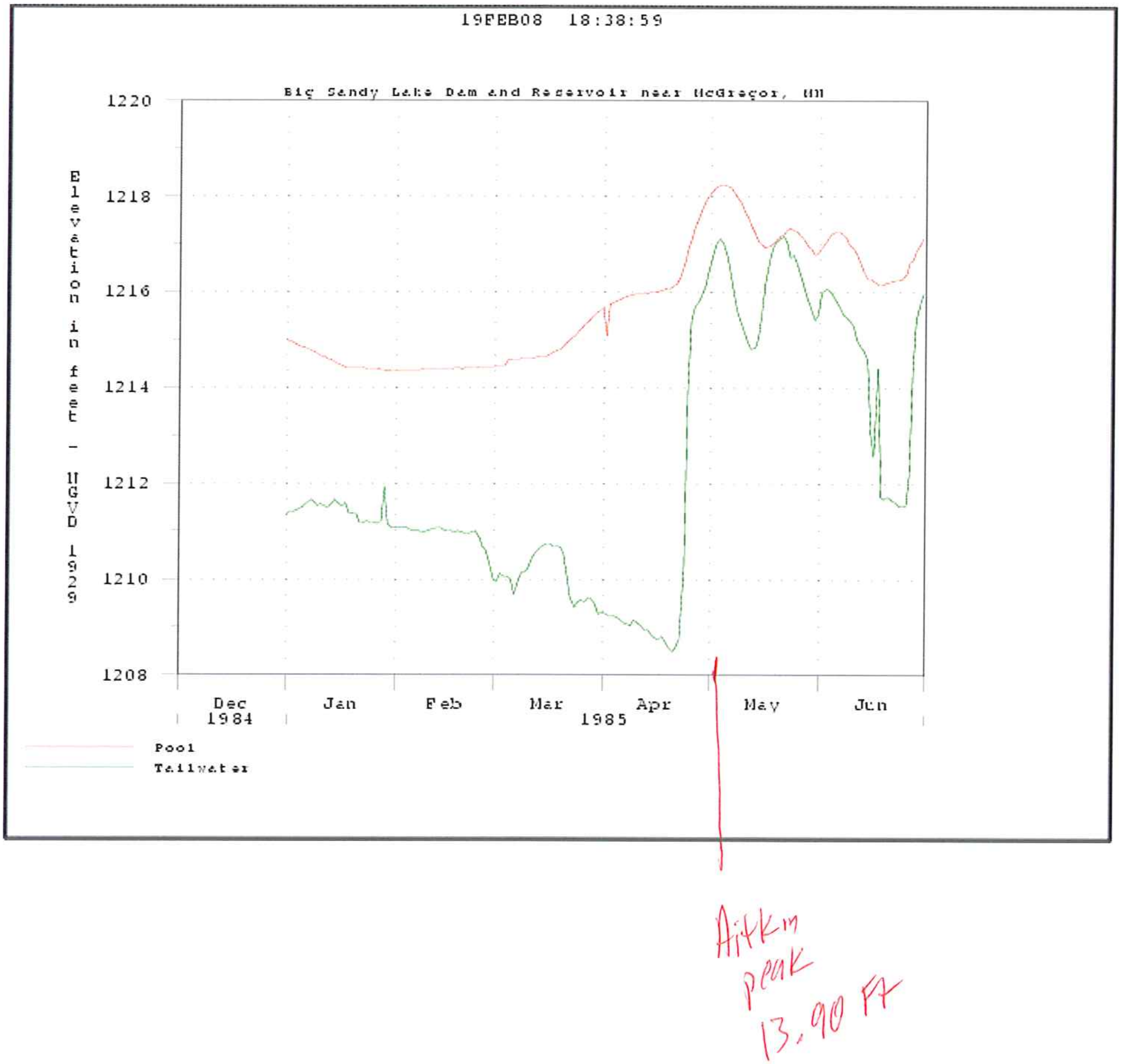
19FEB08 18:40:59

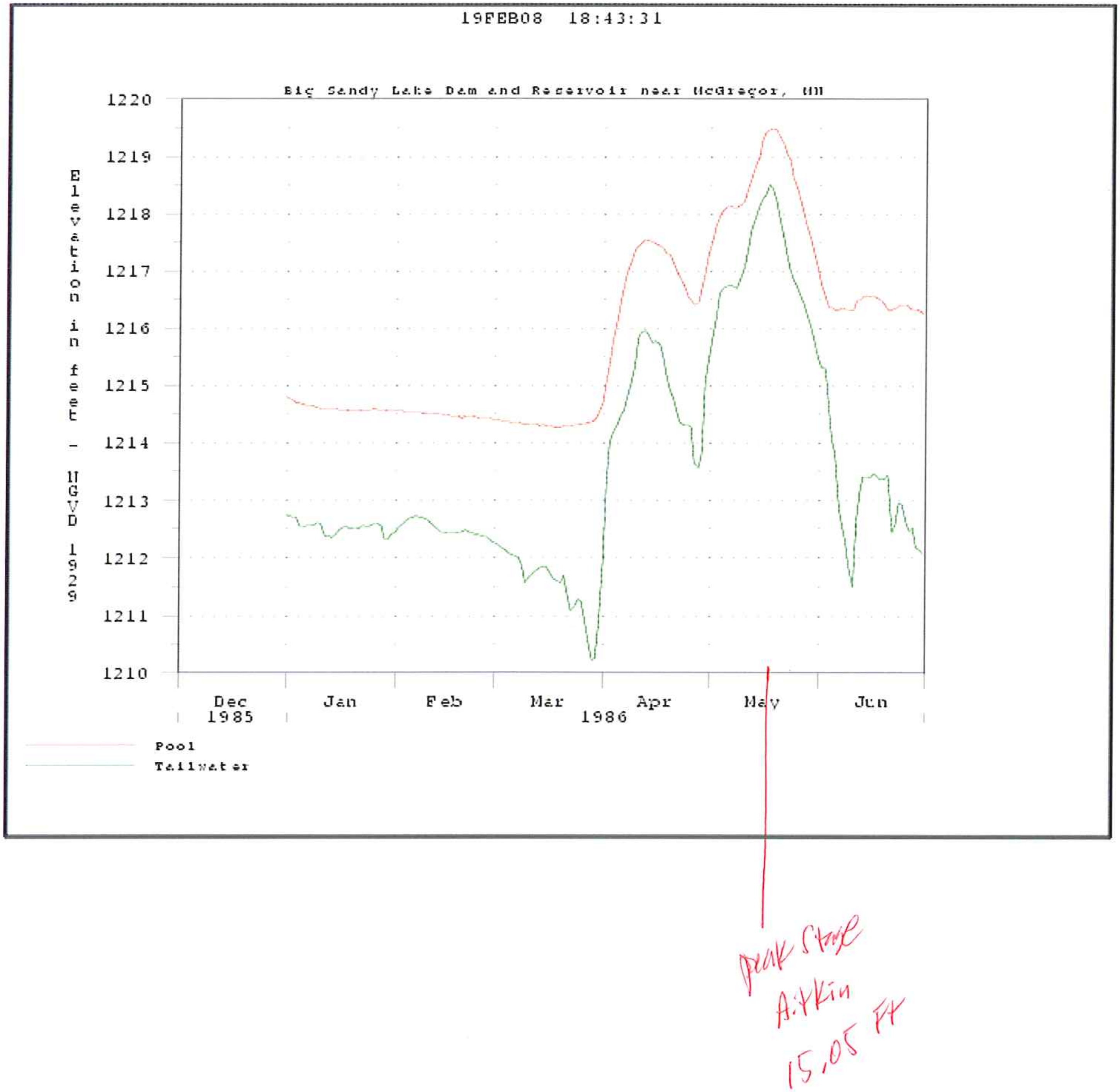


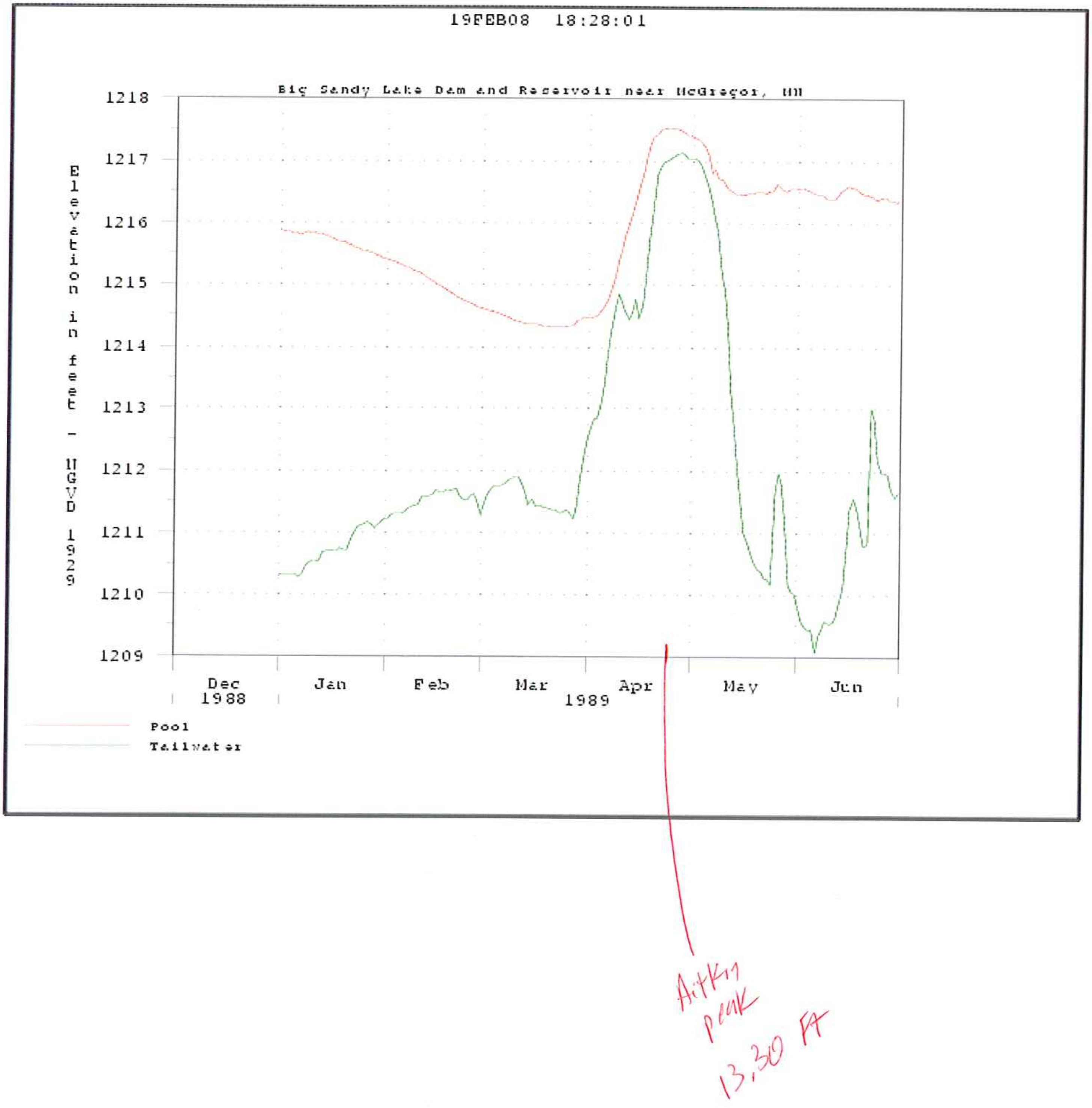


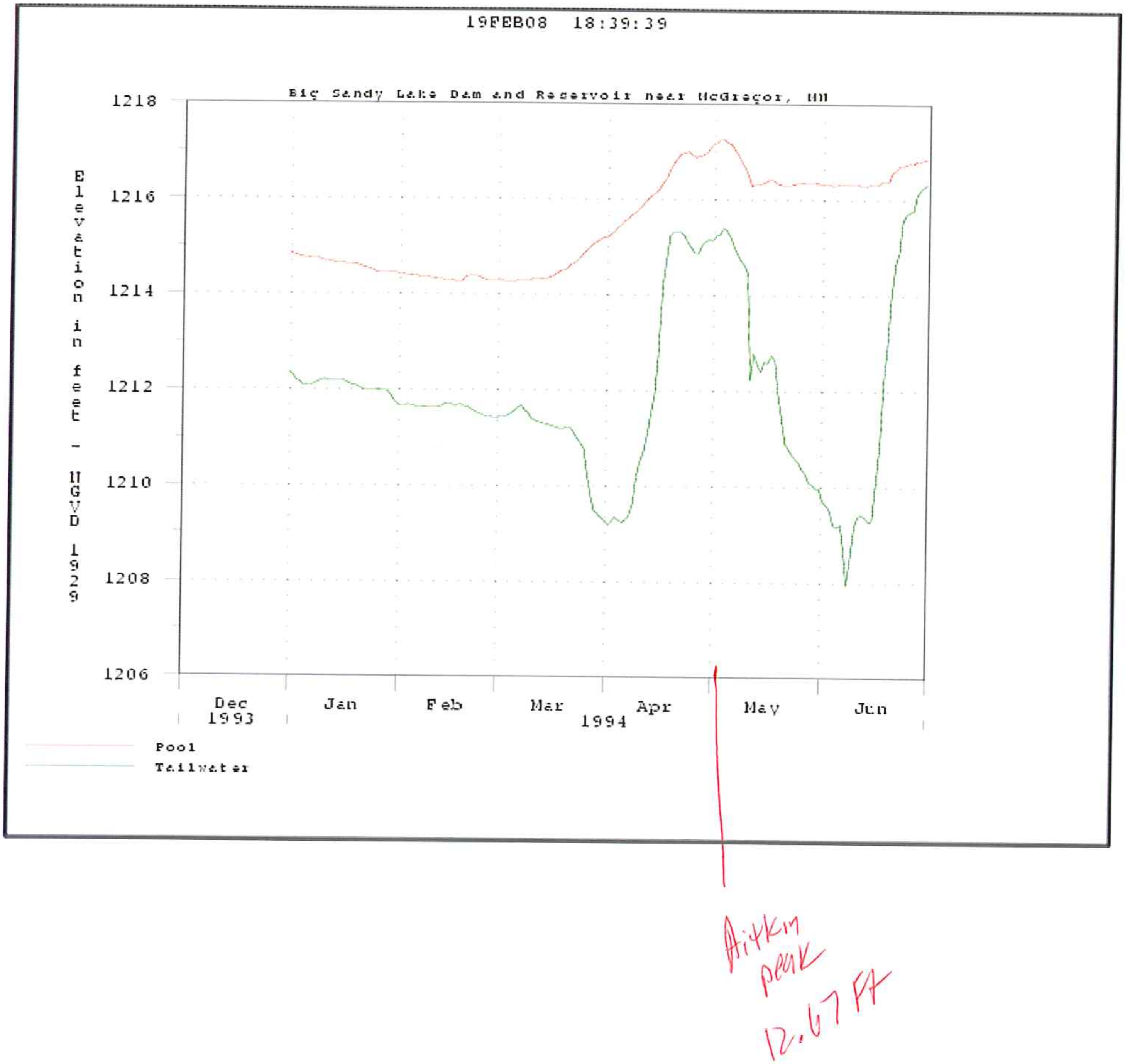
peak
Aitkin Stage
17.05 Ft

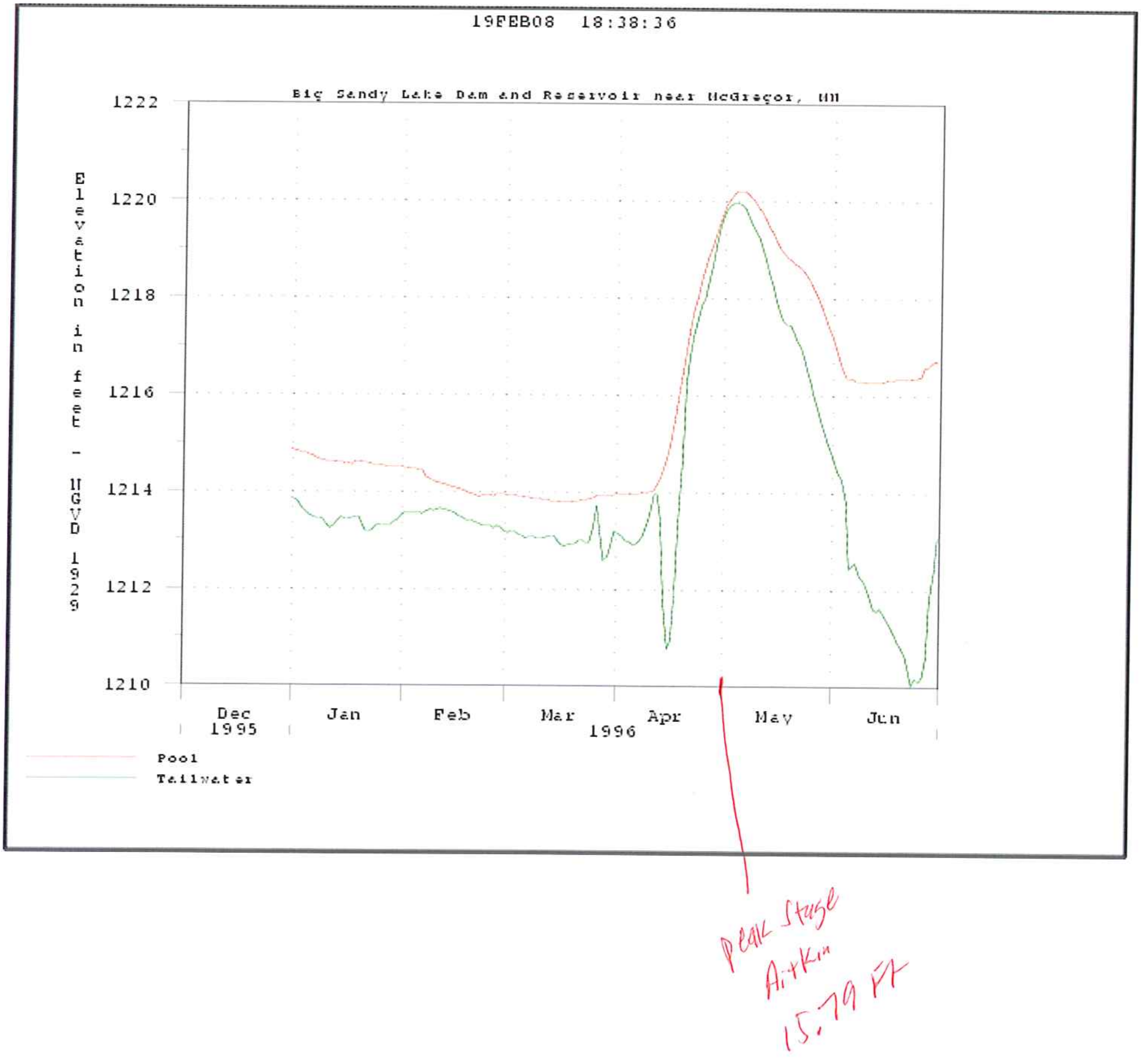

19FEB08 18:29:13
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1220
1219
1218
1217
1216
1215
1214
1213
1212
1211
Dec
1981
Jan
Feb
Mar
1982
Apr
May
Jun
Pool
Tailwater
Peak Aitkin
stage
16.02 Ft

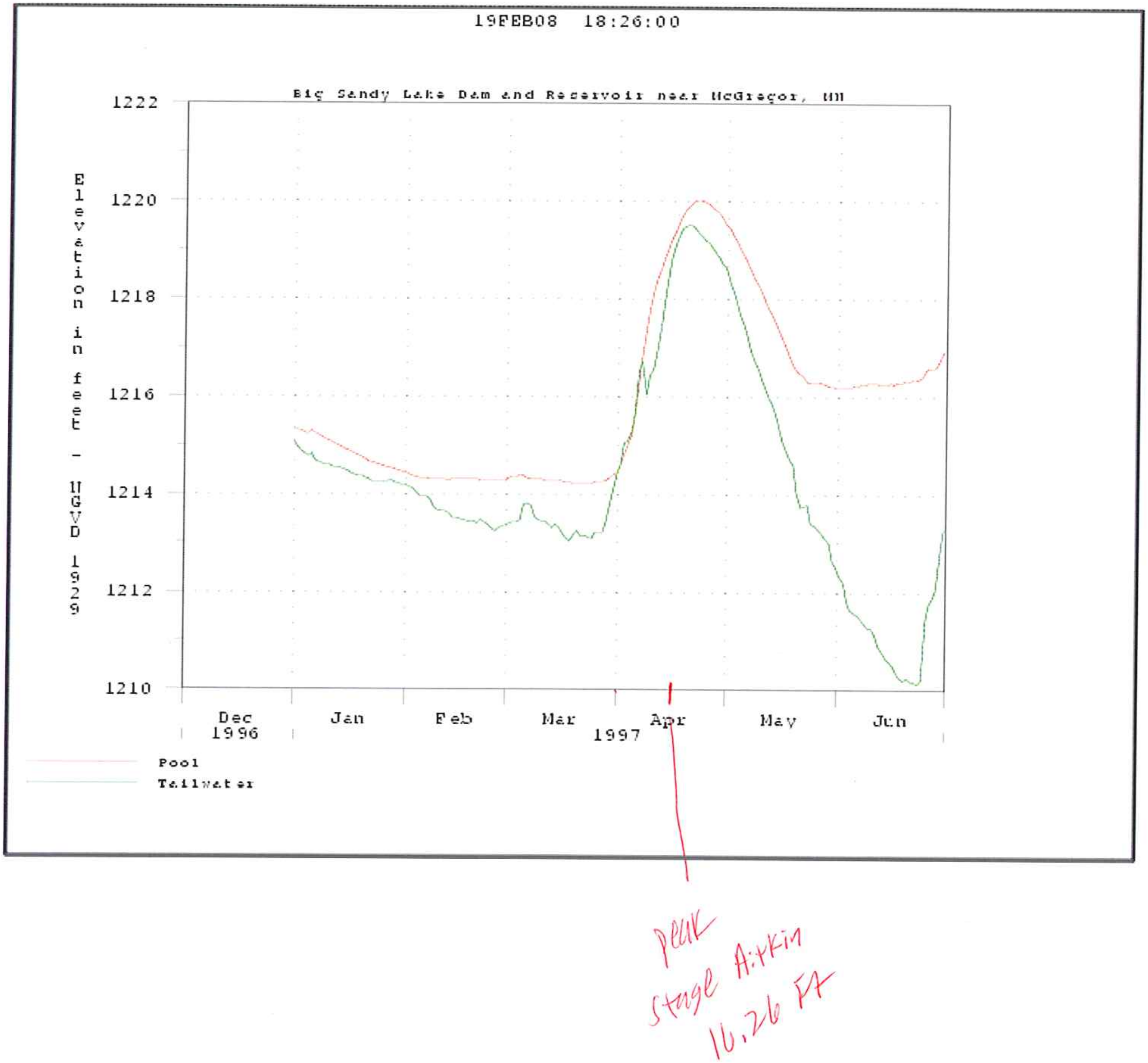

19FEB08 18:38:59
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1220
1218
1216
1214
1212
1210
1208
Dec
1984
Jan
Feb
Mar
1985
Apr
May
Jun
Pool
Tailwater
Aitkin
peak
13.90 Ft

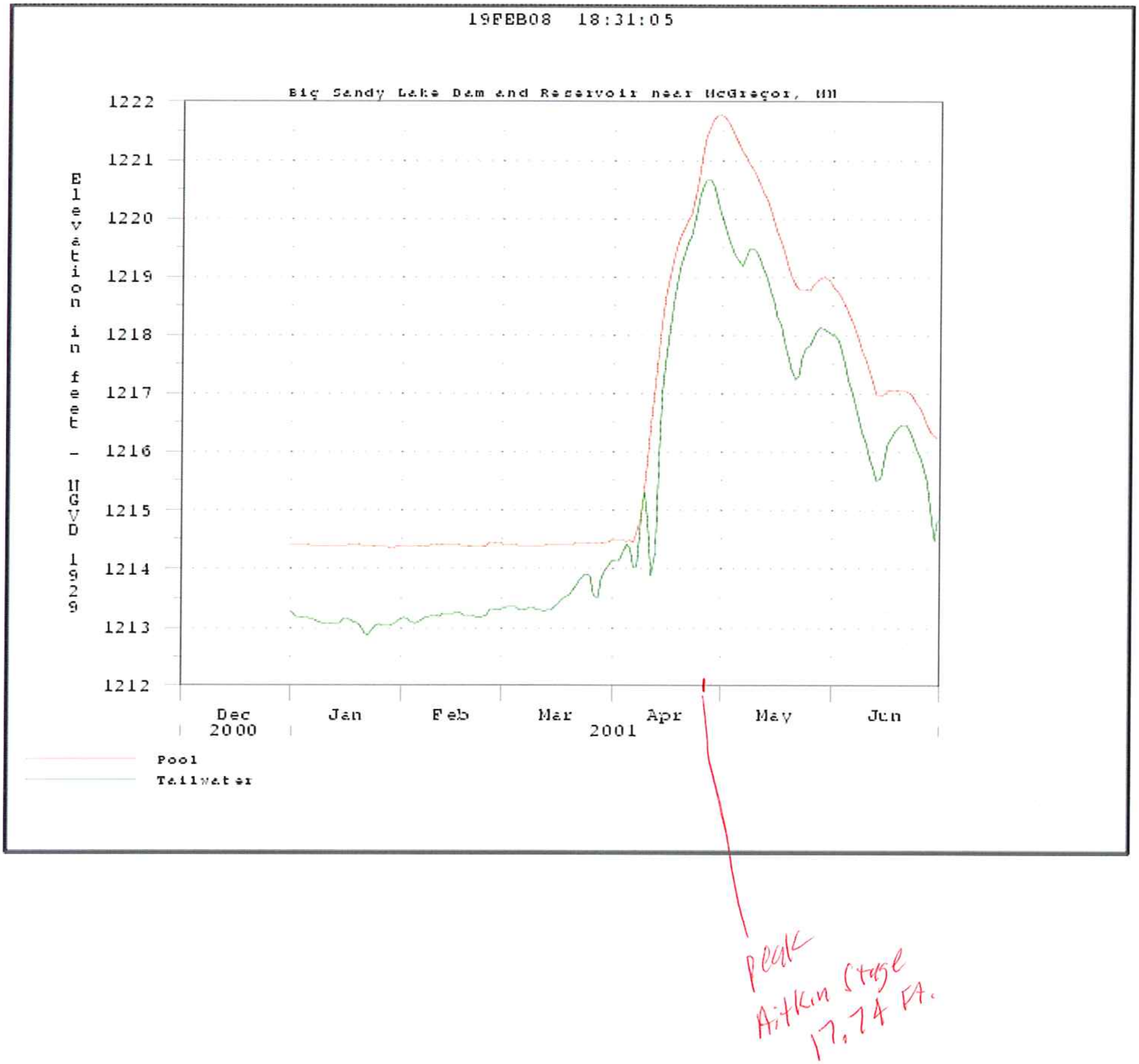

19FEB08 18:43:31
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1220
1219
1218
1217
1216
1215
1214
1213
1212
1211
1210
Dec 1985
Jan
Feb
Mar
Apr
May
Jun
1986
Pool
Tailwater
peak Stage
Aitkin
15.05 Ft

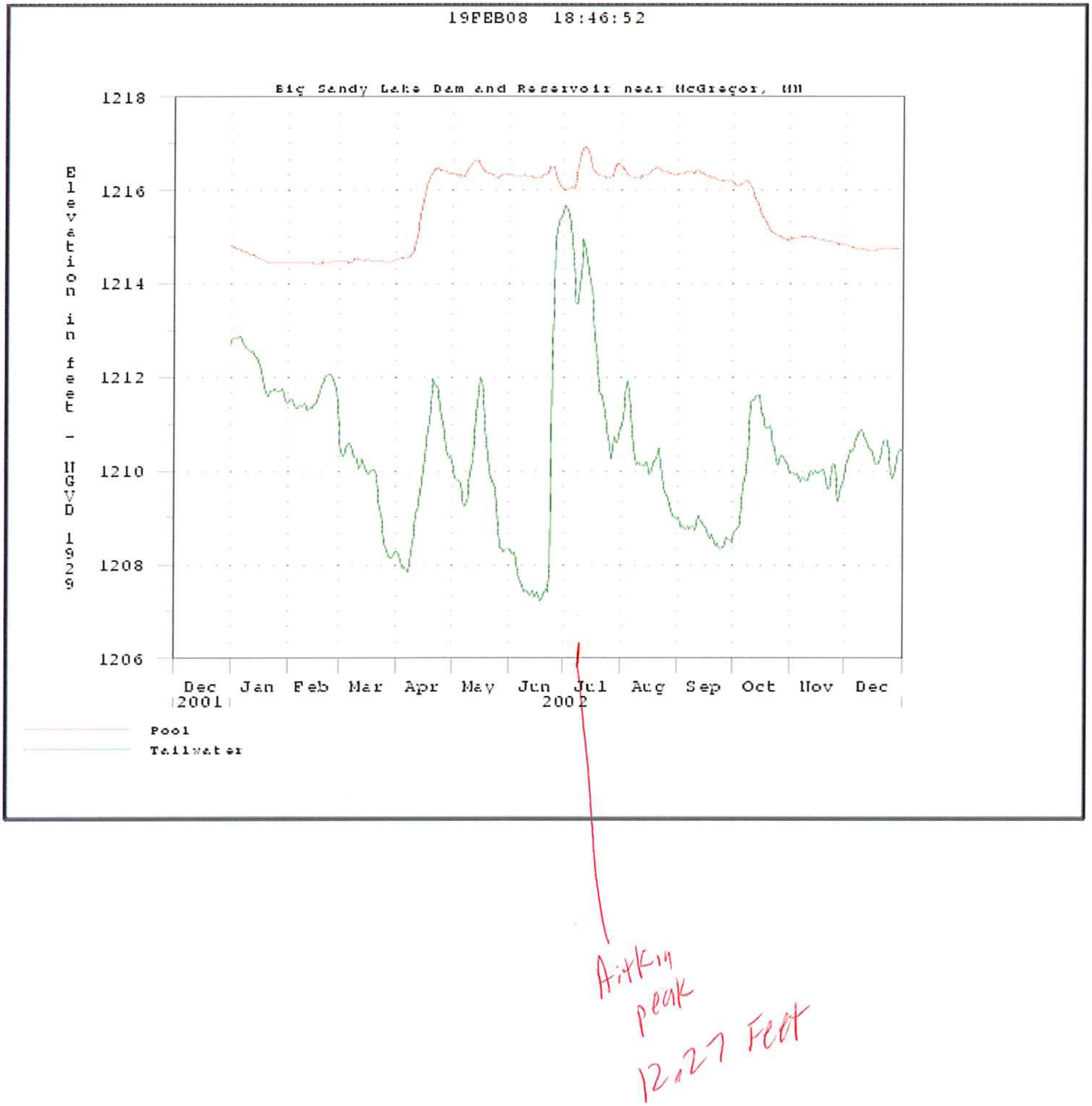

19FEB08 18:28:01
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1217
1216
1215
1214
1213
1212
1211
1210
1209
Dec 1988
Jan
Feb
Mar
Apr
1989
May
Jun
Pool
Tailwater
Aitkin peak
13.30 Ft


19FEB08 18:39:39
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1216
1214
1212
1210
1208
1206
Dec 1993
Jan
Feb
Mar
Apr
1994
May
Jun
Pool
Tailwater
Aitkin peak 12.67 Ft

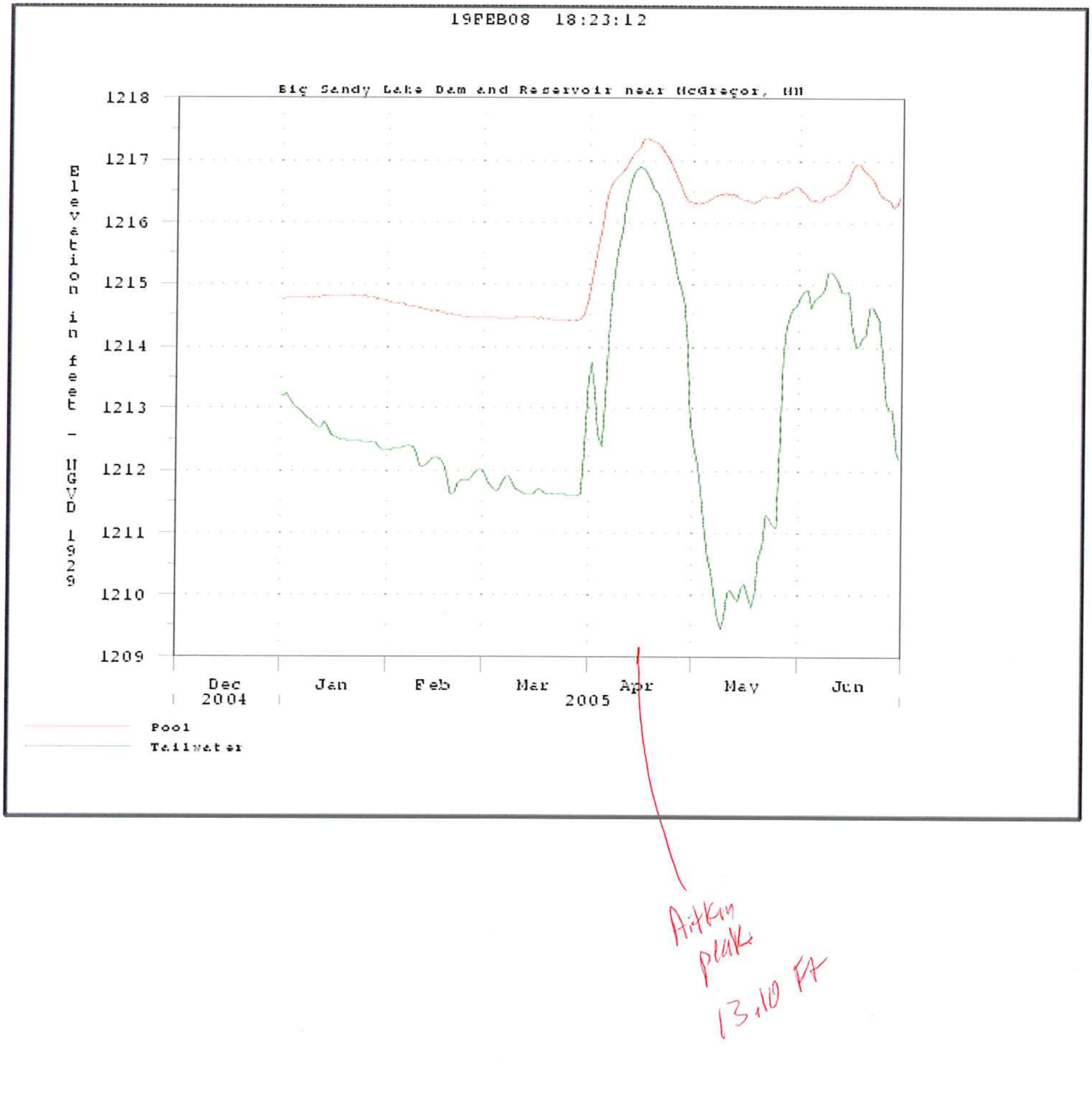

19FEB08 18:38:36
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1220
1218
1216
1214
1212
1210
Dec 1995
Jan
Feb
Mar
1996
Apr
May
Jun
Pool
Tailwater
peak stage
Aitkin
15.79 ft


19FEB08 18:26:00
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1220
1218
1216
1214
1212
1210
Dec 1996
Jan
Feb
Mar
1997
Apr
May
Jun
Pool
Tailwater
peak stage Aitkin 16.26 Ft


19FEB08 18:31:05
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1222
1221
1220
1219
1218
1217
1216
1215
1214
1213
1212
Dec 2000
Jan
Feb
Mar
Apr
2001
May
Jun
Pool
Tailwater
peak
Aitkin Stage
17.74 Ft.



19FEB08 18:46:52
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1216
1214
1212
1210
1208
1206
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2001
2002
Pool
Tailwater
Aitkin peak
12.27 Feet


19FEB08 18:23:12
Big Sandy Lake Dam and Reservoir near McGregor, MN
Elevation in feet - NGVD 1929
1218
1217
1216
1215
1214
1213
1212
1211
1210
1209
Dec
2004
Jan
Feb
Mar
Apr
2005
May
Jun
Pool
Tailwater
Aitkin
peak
13.10 Ft

Appendix G

Minimum Release Guideline Review

Minimum Release Guideline Review
Mississippi Headwaters ROPE Study
May 2008

Introduction

The Reservoir Operation Plan Evaluation (ROPE Study) for the Headwaters Reservoirs of the upper Mississippi River is an effort to improve the dam operations for the benefit of many users. The reservoirs included in the study are: Cass Lake, Lake Winnibigoshish, Leech Lake, Pokegama Lake, Big Sandy Lake, the Whitefish Chain of Lakes, and Gull Lake. The dams on these lakes are operated by the St. Paul District of the U.S. Army Corps of Engineers (COE) with the exception of Knutson Dam on Cass Lake, which is operated by the U.S. Forest Service (FS). Lake Bemidji, which is controlled by Ottertail Power, and Mud and Goose Lakes, which are controlled by a single dam operated by the Minnesota Department of Natural Resources (MNDNR), are also included in the study.

The COE dams are operated under various guidelines and regulations including summer operating bands, water level operating limits, minimum average annual discharge requirements, and minimum release guidelines (see Table 1, rows 4 and 6). The average annual discharge requirements were set by Congress and are normally met with large releases of water in the spring. The minimum flow guidelines are not mandated by law, but were provided by the Minnesota Department of Natural Resources (MNDNR) in the 1960's. The MNDNR guidelines are a set of minimum releases that are followed under normal and dry conditions. They were developed at a time when the dams would be closed to zero flows with little or no consideration to downstream impacts. Even though they were likely based entirely on professional judgment, these guidelines provided a major improvement over the established dam operation prior to the 1960's.

Under extreme drought conditions it may not be possible to meet the Congressional minimum average annual discharge requirements during the spring. Under such conditions it would be necessary to increase the discharge from the reservoirs above the MNDNR minimum flow guidelines in order to meet the minimum average annual discharge. Following completion of the ROPE Study, a change to the Congressional minimum discharge requirements will be sought to avoid these inconsistencies so that one set of minimum release rules would be in place.

Because the MNDNR minimum flow guidelines were created prior to the development of the current body of knowledge on instream flows, it is appropriate to review them under the ROPE. Furthermore, members of the resource management community in the Headwaters feel that the minimum flow guidelines in place now may be inadequate for instream flow needs. The purpose of this review is to examine the current minimum release guidelines and recommend changes to them as warranted.

Table 1. Mississippi River Headwater Reservoir System Operating Elevations

Mississippi River Headwater Reservoir System
Operating Elevations in 1929 NGVD and Stages in Feet

	Winni-bigoshish	Leech	Pokegama	Sandy	Cross L. Pine R.	Gull
1. Normal Summer Range/Band Stage in Feet Middle of the Summer Band Elev.	1297.94-1298.44 9.0 - 9.5 1298.19	1294.50-1294.90 1.8 - 2.2 1294.70	1273.17-1273.67 8.75 - 9.25 1273.42	1216.06-1216.56 8.75 - 9.25 1216.31	1229.07-1229.57 12.75 - 13.25 1229.32	1193.75-1194.00 6.0 - 6.25 1193.87
2. Ordinary Operating Limits Stage in Feet	1296.94-1300.94 8.0 - 12.0	1293.20-1295.70 0.5 - 3.0	1270.42-1274.42 6.0 - 10.0	1214.31-1218.31 7.0 - 11.0	1227.32-1230.32 11.0 - 14.0	1192.75-1194.75 5.0 - 7.0
3. Present/Total Operating Limit Stage in Feet (2002)	1294.94-1303.14 6.0 - 14.2	1292.70-1297.94 0.0 - 5.24	1270.42-1278.42 6.0 - 14.0	1214.31-1221.31 7.0 - 14.0	1225.32-1235.30 9.0 - 18.98	1192.75-1194.75 5.0 - 7.0
4. Federal Regulations, Title 33, Min. Level and Ave. Annual Flow	1294.94 / 6.0 150 cfs	1292.70 / 0.0 70 cfs	1270.42 / 6.0 200 cfs	1214.31 / 7.0 80 cfs	1225.32 / 9.0 90 cfs	1192.75 / 5.0 30 cfs
5. Cong. Notification Levels, Public Law 100-676, Sect. 21, WRDA 88	1296.94/1303.14 8.0 / 14.2	1293.20/1297.94 0.5 / 5.24	1270.42/1276.42 6.0 / 12.0	1214.31/1218.31 7.0 / 11.0	1227.32/1234.82 11.0 / 18.5	1192.75/1194.75 5.0 / 7.0
6. MN Dept. of Natural Resources Minimum Flow Guidelines Min. Release Elevation, Stage and Minimum Flow	≥ 1294.94 / 6.0 100 cfs, < 1294.94 50 cfs	≥ 1292.70 / 0.0 100 cfs, < 1292.70 50 cfs	(See Note No. 6.)	≥ 1214.31 / 7.0 20 cfs, < 1214.31 10 cfs	≥ 1225.32 / 9.0 30 cfs, < 1225.32 15 cfs	≥ 1192.75 / 5.0 20 cfs, < 1192.75 10 cfs
7. Flood Operation, Control Points	Aitkin/Pokegama	Aitkin/Pokegama	Aitkin/Sandy	Aitkin	Ft. Ripley etc.	As Needed
8. Fish Spawn, Operation Guidelines	Fish Spawn	---------	---------	--------	Fish Spawn	--------
9. Flowage Rights Acquired To Elev.: Stage in Feet	1306.86 17.92 +	1301.94 9.24 +	1280.42 16 +	1222.31 15 +	1238.82 22.5 +	1194.75 7
10. Est. Downstream Chan. Cap., cfs	2,000	1,500	6,000	(8.)	2,000-2,500	950
Gage Zero Elev., 1929 NGVD	1288.94	1292.70	1264.42	1207.31	1216.32	1187.75

1. The most desirable levels for the summer season.
2. The Ordinary Operating Limits represent the range that minimizes the degree of high and low water damages. The lower limit is the normal drawdown target level for high snow water content, the exception being Leech which uses 1293.80.
3. The Present Operating Limits are in accordance with the latest regulations from Congress or subsequent studies. The upper and lower limits provide maximum storage for flood control and other purposes.
4. Title 33, Code of Federal Regulations, Sect. 207.340(d) prescribes the min. operating limits and min. ave. annual discharges as set forth in the 1936 and (for Leech) 1944 regulations.
5. Public Law 100-676, Section 21, of the Water Resources Development Act of 1988 requires the Secretary of the Army to notify Congress 14 days prior to a reservoir being below the minimum or above the maximum listed here. The District will notify the Secretary well in advance of the 14-day period.
6. The MDNR elev. and flows are based on an informal agreement between the Corps and the MN Dept. of Natural Resources and are followed after taking measures to insure the federal ave. annual flow requirement is met. When Pokegama is below elev. 1273.17 ft., releases are limited to the sum of the Winni. And Leech discharges. In addition, 200 cfs has been adopted as the minimum discharge when Pokegama is at or above elev. 1273.17 ft.
7. Flowage rights on the Cass L. Chain obtained to elev. 1307.86 (18.92 ft. stage).
8. The channel below Sandy Lake is affected by backwater from the Miss. River. The channel capacity below the confluence of the Miss. River and the Leech Lake River is 2,200 cfs. High flows in the 2,000 to 2,500 cfs range from Pine River Dam cause high water problems on Big Pine Lake.

Methods

Methods for determining minimum flow guidelines, or instream flow recommendations (IFRs), have been evolving for many years. The development of these methods stemmed from the consumptive use of water in streams, most of which occurs in the arid western states. However, these techniques are being applied more consistently in other parts of the country too, particularly on water bodies regulated by dams, as is the case here. A number of “textbook” techniques were used here and the methods for each are described below.

Average Annual Flow Calculations

The methods used here to develop IFRs require hydrologic data, specifically, the average annual flow for a given stream location. Observed flow data from 1931 to 1999 is readily available from all the study reservoirs but Lake Bemidji and Cass Lake. Modeled flow data for unregulated conditions is available from the ROPE STELLA model for all reservoirs during the same time period. With these data, two average annual flows were calculated for each reservoir (Table 2). The simulated unregulated flows were used for the analysis here because they represent as close as possible, a natural flow regime; the methods used here to develop IFRs were developed on river systems with unregulated flow regimes; and simulated data must be used for Cass Lake and Lake Bemidji, as a full historic record is not available.

There is little difference between the observed existing and simulated unregulated mean annual flows because under each scenario the same total volume of water is flowing through the system during any given year. For these two data sets, the timing and the magnitude of specific events would be different, but the calculation for the mean flow would remove most of these differences. Because there is little difference between the observed and simulated values, it is appropriate to use the simulated values, which better represent the natural flows under which the evaluation methods used here were developed.

Table 2. Mean Flows (cfs) 1930-2002.

	Bemidji	*Cass*	*Winni*	*Leech*	*Pokegama*	*Sandy*	*Whitefish*	*Gull*
Observed Existing Mean Flow	na	na	523	396	1198	254	243	127
Simulated Unregulated Mean Flow	191	421			1207	247	248	125

Wetted-Perimeter Methods

The three different techniques used here could be classified as “textbook” methods. These methods are used to develop an estimate of instream flow needs when time and or funding is limited. They rely on readily available hydrologic data and do not require the collection of extensive field data. All three methods used here were based on a wetted-perimeter field method. The wetted-perimeter method determines the flow at which the wetted perimeter of a stream transect begins to decrease at a faster rate with further decreasing flows. When the wetted perimeter vs. flow data is plotted, the minimum IFR is often identified as an “inflection” point.

When this field method is applied to a number of streams in a region and the percentage of the average annual flow at the inflection point is determined for each, it is possible to apply that percentage to similar streams in the region to develop an IFR.

One of the most widely used of these textbook methods was developed by Tenant (1976). Ten years of research on 58 stream cross sections at 38 different flows was used to develop IFRs for differing conditions. The results of this research are reported to be applicable to all streams in all states. The Tenant method identifies seasonally adjusted flow levels to provide different levels of habitat protection (Table 3). The flow at which degradation reportedly begins from April through September is 30% of the mean annual flow. This is often used as the minimum instream flow. Ten percent of the mean annual flow for the same time period is listed as producing poor habitat conditions, and may sustain aquatic life only for brief periods of time. Seasonal flows recommended for 3 levels of habitat protection were calculated and reported for the Headwaters reservoirs in this report.

A statewide instream flow assessment was conducted by the MNDNR from 1985-1987 (Olson et al., 1988). The primary objective of this work was to "…analyze and quantify a conservative (high) approximate range of flows necessary to maintain instream uses throughout the state." In this effort, the state was divided into regions based on stream hydrologic characteristics. Wetted-perimeter vs. water surface elevation was graphed for each study stream and the inflection points were calculated mathematically. In many cases there was more than one inflection point identified for a stream transect. In general, the high-stage inflection point was the normal year IFR and the low-stage inflection point was the dry year IFR. Stages were converted to flows and the percent of the average annual flow for the normal and dry year IFRs were calculated and reported. These instream flows were reported to have combined errors of 35-50 percent. For the Headwaters region, they studied four streams with average mean annual flows ranging from 462 to 38 cubic feet per second (cfs). The average percent of the mean annual flow for a normal year IFR was reported as 82% and the percent reported for a dry year IFR was 53%.

Table 3. Instream Flow Regimes from Tenant (1976) (% of mean annual flow).

Narrative Description of Flow [a]	***April to September***	***October to March***
Flushing or maximum flow	200% from 48 to 72 hours	
Optimum range of flow	60-100%	60-100%
Outstanding habitat	60%	40%
Excellent habitat	50%	30%
Good habitat	40%	20%
Fair or degrading habitat	30%	10%
Poor or minimum habitat [b]	10%	10%
Severe degradation	<10%	<10%

[a] For fish, wildlife, recreation, and related environmental resources
[b] This is only for short-term survival in most cases

O'Shea (1995) developed two linear regression models to develop IFRs for streams in Minnesota. One model predicted the IFR based on mean annual flow only, and the other predicted IFR based on drainage area and soil type. The models were developed with the same field data collected by

Olsen et al. (1988), and were also based on the wetted-perimeter field method. The model developed with mean annual flow performed better than the one based on drainage area and soil type. For the Headwaters ROPE review, the linear regression model based on mean annual flow was used: IFR = 14.898 + 0.654(QMean). The standard error for this equation was 28.1 cfs and the regression coefficient was significant.

Results

The existing minimum release guidelines and the results of this low flow review can be found in Tables 4 and 5. The current minimum flow guidelines in most cases are less than the minimum flows recommended by all three textbook methods. Tennant does not recommend 10% of the MAF as a minimum flow, but states that at this level, poor habitat conditions are present and this would only be suitable for a minimum short-term survival flow. The current minimum release for Big Sandy Lake is below 10% of the MAF.

The Tennant method here resulted in the lowest IFRs, followed in increasing order by Oslon et al. dry year, O'Shea, and Olson et al. normal year. Roughly, for a dry year Olson et al. recommends 53% of MAF, O'Shea recommends 65% of MAF, and for a normal year Olson et al. recommends 82% of MAF.

Table 4. Current Minimum Release Guidelines.

		Cass	*Winni*	*Leech*	*Pokegama*	*Sandy*	*Whitefish*	*Gull*
Existing Normal Minimum Release	-	~100	100	100	200	20	30	20
Existing Dry Minimum Release	-	~100	50	50	W+L	10	15	10
Congressional Min Ave Release	-	-	150	70	200	80	90	30

Table 5. Instream Flow Recommendations.

	Bemidji	*Cass*	*Winni*	*Leech*	*Pokegama*	*Sandy*	*Whitefish*	*Gull*
Tennant (Apr-Sep, 40%, good)	76	168	212	158	483	99	99	50
Tennant (Oct-Mar, 20%, good)	38	84	106	79	241	49	50	25
Tennant (Apr-Sep, 30%, degrading)	57	126	159	118	362	74	74	38
Tennant (Oct-Mar, 10%, degrading)	19	42.1	53	39	121	25	25	12
Olson et al., 1988 (normal – 82%)	157	345	435	323	990	202	203	102
Olson et al., 1988 (dry – 53%)	101	223	281	209	640	131	131	66
O'Shea, 1995 (~ 65% + 15)	140	290	362	273	804	176	177	97

Recommendation

The minimum flow guidelines currently in place on the study reservoirs are below the instream flows recommended by all three methods used here. Therefore, recommending an increase to the current minimum releases is justified. However, the question still remains as to how much the increases should be, and which method to base them on. If the decision were only based on the integrity of instream habitat, it may be reasonable to select the most conservative (high) minimum releases. Improved riverine habitat conditions would increase biological productively and could lead to higher numbers of fish. Instream recreation would be improved by providing higher flows needed for canoeing and kayaking. Reservoir habitat would be improved by facilitating a more natural seasonal drawdown, rather than the fast drawdown that currently takes place during the winter. The diversity and abundance of emergent aquatic vegetation on the reservoirs would also be improved, providing habitat for birds, fish, aquatic mammals and other organisms. However, there are potential negative aspects of increasing minimum releases related to the decreased ability to maintain reservoir water levels during the summer months. This could have a negative impact on certain aspects of recreation such as increasing navigational hazards, decreasing dock accessibility, and decreasing boat ramp suitability. All of these factors were considered in developing the minimum flow guidelines below.

The method used by Olson et al. produced conservative (high) minimum flow recommendations. Their most conservative recommendation was for normal flow years and is roughly three to 10 times higher than the existing minimum flow guidelines. Such increases in minimum flows would be difficult to justify when considering the costs of these flows and the error associated with the recommended flow estimate. Similarly, the method used by O'Shea (1995) resulted in major increases in minimum instream flows. While both of these methods were based on data from streams in Minnesota and could arguably be most applicable to the Headwaters reservoirs, they were admittedly conservative (high).

The Tenant (1976) method as used here produced the most appropriate IFRs for two reasons. For one, while the Tennant IFRs for the study reservoirs are typically at least twice the current minimum flow guidelines, they deviate from current minimum releases the least of any method here. Because of this, applying these IFRs would have the least impact on reservoir water levels. Second, they are seasonally divided to allow lower flows during the winter months when it is more appropriate for aquatic life. The lower winter IFR would also allow more flexibility in dam operation to ensure the maintenance of adequate water levels following the proposed higher summer and fall releases.

There are two primary aspects of the minimum flow guidelines. One is the minimum flow, and the other is the reservoir "condition" or elevation at which the minimum flow requirement would change. The preceding discussion has covered the development of the minimum flow, but nothing has as yet been provided covering the different reservoir conditions. It is intuitive that different minimum flows could be triggered based on seasonal precipitation and the severity of dry weather (i.e., changes in drought conditions). This would allow the change in minimum release to be changed depending on inflow. However, reservoir operation rules that are related directly to water elevation are objective, simple for reservoir operators to implement, and are simple for stakeholders to understand. Furthermore, impacts to other reservoir uses such as recreation are directly dependant on water elevation. For these reasons, it was decided to continue to relate minimum release requirements to water elevation.

As mentioned above, recreational use of the reservoirs is directly impacted by water elevation. Because of this and because recreational use of these reservoirs is significant, declining water levels caused by increases in minimum release requirements are a major concern. Therefore, the potential social impact relative to minimum release changes was given major consideration in developing the reservoir "condition" elevations at which different minimum release requirements would be implemented. The reasoning behind the selection of these condition elevations is given below.

The recommended minimum release rules (also referred to as IFRs) can be found in Tables 6 and 7. Table 6 gives the summer minimum release rules, and table 7 gives the winter minimum release rules. The values in these tables were taken from table 5 and rounded to the nearest ten. A discussion of the minimum release rules follows.

Summer (April 1st through September 31st) Minimum Releases

Summer minimum releases were developed for 4 different reservoir conditions. This was done for two reasons. First, the summer months are when most water-level dependent recreation occurs, and a plan that is more sensitive to water levels would help reduce negative impacts. Second, the summer months are also when aquatic organisms are most sensitive to low flows. During winter months lower flows occur naturally and cold water will hold more oxygen, which is a critical factor under low flows.

High Summer Reservoir Condition

The "high" reservoir condition is in effect when reservoir water levels are equal to or greater than the targeted water level for a given time of year (i.e., the operating target that is put into effect following completion of the ROPE Study). When a reservoir is in the "high" condition, there would be no negative impact to recreation under a higher minimum release. Therefore, the minimum release would be set at the 40% of MAF, or the "good" condition from Tenant.

Normal Summer Reservoir Condition

The "normal" reservoir condition is in effect when reservoir water levels are lower than the target but greater than the target minus 3 inches. A drop in water levels of 3 inches from the target frequently occurs under the existing plan, and therefore, is considered within the range of normal fluctuation. For normal water level conditions the "degrading" habitat level recommendation from Tenant was selected. For summer months, this is 30% of the mean annual flow. This is what is typically selected for a minimum flow in cases where the Tenant method is applied. It is expected that the reservoirs will most often be in this condition and it is expected that these minimum flows will be followed most of the time.

Low Summer Reservoir Condition

The "low" reservoir condition would occur under dry conditions. Reservoir water levels in the range of the target minus 3 inches down to and above the target minus 18 inches are considered "low". Low water levels would have a negative impact on recreation and therefore, minimum releases would be reduced. For the low condition the "fair or degrading" habitat flow level from Tenant was chosen, which is 20% of the MAF. Reducing minimum flows lower than this for an extended period of time is not recommended by Tenant.

Very Low Summer Reservoir Condition

The "very low" reservoir condition would occur under extremely dry conditions. Reservoir water levels less than the target minus 18 inches would be considered "very low". For very low conditions, 10% of the mean annual flow was chosen as the minimum release for all months of the year. Flows less than 10% of the mean annual flow are generally not considered adequate to maintain aquatic life for an extended period of time.

Winter (October 1st through March 31st) Minimum Releases

Winter minimum flow releases were developed for two reservoir conditions. There are fewer conflicts with water-level dependent recreation, and low flows are less critical to aquatic life. Operating for two reservoir conditions also simplifies operation.

Normal Winter Reservoir Condition

The "normal" winter reservoir condition is in effect when reservoir water levels are at or above the target minus 6 inches. Minimum releases would be 20% of the MAF, which is considered as "good" by Tenant for the winter months.

Low Winter Reservoir Condition

The "low" winter reservoir condition is in effect when reservoir water levels are below the target minus 6 inches. Minimum releases would be 10% of the MAF, which is considered as "degrading" by Tenant for the winter months.

Table 6. Summer Minimum Flow (cfs) Guidelines April 1st through September 30th.

Reservoir Condition	Reservoir Elevation	*Bemidji*	*Cass*	*Winni*	*Leech*	*Pokegama (lesser of)*	*Sandy*	*Whitefish*	*Gull*
High	**>= Target**	80	170	210	160	W+L+ 110 or 480	100	100	50
Normal	**< Target to >= Target – 3"**	60	130	160	120	W+L+80 or 360	70	70	40
Low	**Target – 3" to >= Target – 18"**	40	80	110	80	W+L+50 or 240	50	50	20
Very Low	**< Target – 18"**	20	40	50	40	W+L+30 or 120	20	20	10

Table 7. Winter Minimum Flow (cfs) Guidelines October 1st through March 31st

Condition	Reservoir Elevation	*Bemidji*	*Cass*	*Winni*	*Leech*	*Pokegama (lesser of)*	*Sandy*	*Whitefish*	*Gull*
Normal	**>= Target – 6"**	40	80	110	80	W+L+50 or 240	50	50	20
Low	**< Target – 6"**	20	40	50	40	W+L+30 or 120	20	20	10

Effects of New Minimum Release Plan of Current Plan

The recommended minimum flow plan will be analyzed with the ROPE analytical models to determine their effects on flows and water levels. If these or a variation of these minimum flow guidelines are implemented, the ROPE Study process will be used to do so and the requirements of the National Environmental Policy Act will be met under the ROPE Environmental Impact Statement. A very brief discussion of some of the potential effects of this minimum release plan follows, categorized by season and reservoir condition.

One concern is that increasing minimum flows over the existing minimums would inhibit the Corps' ability to maintain target reservoir water elevations. During wetter periods of the year, increases in minimum releases proposed here should have a limited effect on the ability to hold water elevations near target levels. However, during the later half of summer when inflows are normally decreased, a higher minimum release could cause water levels to decline below the targeted elevation, thereby making it difficult to follow the prescribed water levels. The proposed operating plan from the ROPE study includes a built-in lowering of reservoir levels during the last half of summer. The targeted drop per month after July 15th in the proposed plan is listed in Tables 8-11. Tables 8-11 also show the additional drop per month that would be caused by increased minimum flows as recommended. Providing the targeted drop per month after July 15th in the proposed plan is greater than the increased drop per month induced by the increase in minimum releases, it is reasonable to assume that there would be no net affect in the Corps' ability to maintain targeted water levels under the proposed plan. In effect, the increase in minimum flows is built into the proposed plan to some degree.

Pokegama is a notable exception to the general effects of the minimum release plan because the current minimum release for Pokegama is unique. The existing plan for Pokegama basically states that the release minimum would be equal to the combined outflow from Winnibigoshish and Leech. This rule does not take into account local inflow to Pokegama downstream of these reservoirs and, therefore, the "cost" to Pokegama at minimum flows is effectively zero. Under extremely dry conditions this could lead to extremely low releases and downstream flows, uncharacteristic of natural conditions on a river with a drainage area of a similar size. The evaluation here recognizes the entire watershed contributing to Pokegama's inflow and fairly sets the minimum releases relative to this, rather than an artificial inflow based only on what is released from Winnibigoshish and Leech.

High Summer Reservoir Condition

The increase flows over the current minimum release plan for the high summer condition are shown for each reservoir in Table 8. Under this condition there would be no negative effect to reservoir recreation because increases in minimum flows here only apply when reservoir water elevations are grater than the target. However, there is a potential for increased river stages downstream that could be a negative effect during floods. This is however a minor increase in flow relative to flood flows.

Table 8. Minimum Flows Under Current and Proposed Rules – High Summer Condition.

High Summer Condition	***Bemidji***	***Cass***	***Winni***	***Leech***	***Pokegama (lesser of)***	***Sandy***	***Whitefish***	***Gull***
Current Minimum	-	~100	100	100	200	20	30	20
Proposed Minimum	80	170	210	160	W+L+ 110 or 480	100	100	50
Difference	-	+70	+110	+60	+110*	+80	+70	+30
Drop/Month (in.) Due to Increased Minimum			1.33	0.36	5.24	6.15	3.68	1.67
Drop/Mo (in) after 15 July in Proposed Plan	0.6	1.8	1.86	1.50	3.18	2.58	2.58	1.44

* For Pokegama, this is the increase in outflow over inflow.

Normal Summer Reservoir Condition

Under the normal condition there would be an increase in outflow (roughly doubling) over the current plan as shown in Table 9. Because the prescribed lowering of reservoir water elevations during the last half of summer is greater than the lowering induced by increased minimum flows on Winni, Leech, Whitefish, and Gull, there would be no adverse effect in late summer as discussed above. However, the drop induced by the new minimum flow is greater than the targeted drop for Pokegama and Sandy. The net increase in drop per month for Pokegama and Sandy would be 0.63 and 1.27 inches, respectively. It is possible however, that during dry periods other than late summer, there could be a decrease in the ability to maintain target water levels on all the reservoirs.

Table 9. Minimum Flows Under Current and Proposed Rules – Normal Summer Condition.

Normal Summer Condition	*Bemidji*	*Cass*	*Winni*	*Leech*	*Pokegama (lesser of)*	*Sandy*	*Whitefish*	*Gull*
Current Minimum	-	~100	100	100	200	20	30	20
Proposed Minimum	60	130	160	120	W+L+80 or 360	70	70	40
Difference	-	+30	+60	+20	+80*	+50	+40	+20
Drop/Month (in.) Due to Increased Minimum			0.72	0.12	3.81	3.85	2.11	1.11
Drop/Mo (in) after 15 July in Proposed Plan	0.6	1.8	1.86	1.50	3.18	2.58	2.58	1.44

* For Pokegama, this is the increase in outflow over inflow.

Low Summer Reservoir Condition

Under the low condition minimum releases increase over the existing minimums slightly for Winnibigoshish, Pokegama, Sandy, and Whitefish. The increase in water elevation drop is generally less than two and half inches per month. The minimum release would decrease for Cass and Leech and remain unchanged for Gull and, therefore, would result in no net loss in water levels over the existing plan for these reservoirs.

Table 10. Minimum Flows Under Current and Proposed Rules – Low Summer Condition.

Low Summer Condition	*Bemidji*	*Cass*	*Winni*	*Leech*	*Pokegama (lesser of)*	*Sandy*	*Whitefish*	*Gull*
Current Minimum	-	~100	100	100	W+L	20	30	20
Proposed Minimum	40	80	110	80	W+L+50 or 240	50	50	20
Difference	-	-20	+10	-20	+50*	+30	+20	0
Drop/Month (in.) Due to Increased Minimum			.12	-.12	2.38	2.31	1.05	0.00
Drop/Mo (in) after 15 July in Proposed Plan	0.6	1.8	1.86	1.50	3.18	2.58	2.58	1.44

* For Pokegama, this is the increase in outflow over inflow.

Very Low Summer Reservoir Condition

The “very low” reservoir condition would result in a reduction or no change in minimum releases for all reservoirs except Pokegama. Therefore, under extremely dry conditions, the proposed minimum release plan would release less or the same water from all reservoirs but Pokegama, over the existing plan.

Table 11. Minimum Flows Under Current and Proposed Rules – Very Low Summer Condition.

Very Low Summer Condition	*Bemidji*	*Cass*	*Winni*	*Leech*	*Pokegama (lesser of)*	*Sandy*	*Whitefish*	*Gull*
Current Minimum (at target - 18”)	-	~100	100	100	W+L	20	30	10
Proposed Minimum	20	40	50	40	W+L+30 or 120	20	20	10
Difference	-	-60	-50	-60	+30	0	-10	0
Drop/Month (in.) Due to Increased Minimum			-0.60	-0.36	1.43	0.00	-0.53	0.00
Drop/Mo (in) Aug 1 to Oct 1 in Proposed Plan	0.6	1.8	1.86	1.50	3.18	2.58	2.58	1.44

* For Pokegama, this is the increase in outflow over inflow.

Winter (October 1st through March 31st) Minimum Releases

Impacts of the proposed minimum releases for winter months are similar to those for the summer months, except there is no effect on boating. Because of this, the significance of the effects of increased minimum releases is greatly reduced.

Normal Winter Reservoir Condition

Minimum releases under the "normal" winter reservoir condition would be in effect when reservoir water levels are at or above the target minus 6 inches. This is a decrease in releases over the existing plan for Cass and Leech, and an increase for the others. Again, the gradual drawdown in the proposed plan helps account for this during the winter as it does in late summer.

Table 12. Minimum Flows Under Current and Proposed Rules – Normal Winter Condition.

Normal Winter Condition	*Bemidji*	*Cass*	*Winni*	*Leech*	*Pokegama (lesser of)*	*Sandy*	*Whitefish*	*Gull*
Current Minimum	-	~100	100	100	W+L	20	30	10
Proposed Minimum	40	80	110	80	W+L+50 or 240	50	50	20
Difference	-	-20	+10	-20	+50	+30	+20	+10

* For Pokegama, this is the increase in outflow over inflow.

Low Winter Reservoir Condition

The change in "low" winter releases represents a decrease in releases from the existing plan for all reservoirs but Pokegama. Therefore, it would increase the ability to retain reservoir water levels over the existing plan under very dry conditions.

Table 13. Minimum Flows Under Current and Proposed Rules – Low Winter Condition.

Low Winter Condition	*Bemidji*	*Cass*	*Winni*	*Leech*	*Pokegama (lesser of)*	*Sandy*	*Whitefish*	*Gull*
Current Minimum	-	~100	100	100	W+L	20	30	10
Proposed Minimum	20	40	50	40	W+L+30 or 120	20	20	10
Difference	-	-60	-50	-60	+30	0	-10	0

* For Pokegama, this is the increase in outflow over inflow.

Table 14. Increase in outflow required to lower reservoirs 1 inch per month.

Bemidji	*Cass*	*Winni*	*Leech*	*Pokegama*	*Sandy*	*Whitefish*	*Gull*
-		83	167	21	13	19	18

References

Olson, P. L., H. Drewes, and D. Desotelle. 1988. Statewide instream flow assessment. Minnesota Department of Natural Resources, Division of Waters, Technical Report 1985-1987 to the Legislative Commission on Minnesota Resources, St. Paul.

O'Shea, D. T. 1995. Estimating minimum instream flow requirements for Minnesota streams from hydrologic data and watershed characteristics. North American Journal of Fisheries Management 15:569-578.

Tennant, D. L. 1976. Instream flow regimes for fish, wildlife, recreation, and related environmental resources. Fisheries 1(4):6-10.

Appendix H

Brief History of the Headwaters Reservoirs

BRIEF HISTORY OF THE HEADWATERS RESERVOIRS

INTRODUCTION

Shaped in the retreat of the last Ice Age, the Minnesota landscape is marked by countless lakes, ponds, and bogs that feed into three major North American watersheds and give rise to the “Mighty Mississippi” River, the nation’s most important natural highway. The Mississippi flows north out of Lake Itasca in the Headwater Region of north central Minnesota before plunging east and then south along a path that carries it through the agricultural heartland of the United States to the Gulf of Mexico. But the Headwaters no longer constitute a natural river system. Desirous of improving navigation on the Mississippi River through the Twin Cities, Congress authorized the Corps of Engineers to construct six dams in the headwaters between 1880 and 1907. Flour millers at St. Anthony Falls especially pushed for reservoirs above the falls, recognizing that the release of water from the reservoirs for navigation in the later summer and fall would increase the flow of water to keep their mills turning longer and more consistently.

Congress initially refused the project based on its pork-barrel appearance. In 1880, however, it finally authorized an experimental dam for Lake Winnibigoshish and authorized the remaining dams shortly afterwards. The Headwaters project provided for construction of the Winnibigoshish Dam in 1883-1884 and the completion of dams at Leech Lake (1884), Pokegama Falls (1884), Pine River (1886), Sandy Lake (1895), and Gull Lake (1912). In its 1895 Annual Report, the Corps of Engineers reported that releasing the water from the Headwaters reservoirs had successfully raised the water level in the Twin Cities by 12 to 18 inches, helping navigation interests and the millers. Within the Headwaters, though, the impoundment of large volumes of water and subsequent controlled fluctuations of water levels had a profound -- and almost entirely negative -- impact on tribal lands adjacent to the region.

ORIGINS OF THE HEADWATER DAMS

Congress first directed the Army Corps of Engineers to construct a series of reservoirs along the remote upper reaches of the Headwaters in 1880, but the origins of those dams goes back to mid-century. Since at least 1850, the Army Corps of Engineers, as well as private commercial interests, had been investigating the feasibility of damming the headwaters in order to regulate flow of the river downstream. The millers and other users of waterpower in Minneapolis were especially eager to have a constant flow over St. Anthony Falls during low water periods. Prominent American engineers such as Franklin Cook, Charles Ellet, Jr., and Thomas M. Griffith supported the concept of a headwaters reservoir system; and William D. Washburn, a leading Minneapolis miller and United States senator, led the campaign for a federally funded reservoir project. Townspeople along the Mississippi River supported the proposal because they believed that enhancing the river's flow would boost navigation and restore competition in the region's transportation industry, which was virtually monopolized by the railroads. The city of Minneapolis enthusiastically supported the idea, envisioning itself as the seat of navigation for a new and burgeoning river traffic between the Falls of St. Anthony and the northern Minnesota frontier.

As it became clear that the construction and maintenance of a reservoir system in the Mississippi headwaters would greatly benefit private business interests, Congress instructed the Army Corps of Engineers to investigate whether the public would benefit from the project. At the time, periodic changes in the water levels of the river between the headwaters and Lake Pepin made steamboat navigation impossible for weeks, and sometimes months, at a stretch. Because few boats plied the Mississippi above St. Anthony Falls, the Corps had to make the case that navigation below St. Paul could be improved by the release of water from reservoirs in northern Minnesota. For this reason the engineers recommended the reservoir system, and Congress authorized the construction of an experimental dam at the outlet of Lake Winnibigoshish in 1880. Construction at Winnibigoshish began in the winter of the following year, and the Pokegama Falls and Leech Lake dams were commenced in 1883. Despite delays caused by poor transportation connections, severe weather, and the need to work around heavy logging operations, the three dams were completed and functioning by 1884. A fourth dam downriver of Grand Rapids on the Pine River outlet of the Whitefish chain of lakes was built in 1885 and put into operation in 1886.

When released water from the first three reservoirs reached the lowlands around Aiken, it caused a back up in the Sandy River and into Sandy Lake. A dam was constructed on the Sandy River and formed a fifth reservoir. Construction on that dam began the following year and was completed in 1884. Additional Congressional authorizations and appropriations allowed the Corps to build two more dams, one at Leech Lake and one at Lake Pokegama, between 1882 and 1884. Over the next 28 years the government engineers completed the last three dams in the system of headwater reservoirs at Pine River (Cross Lake) and Sandy and Gull Lakes. The development of these reservoirs required Ojibway land.

THE EFFECTS OF THE HEADWATER DAMS ON OJIBWAY LIFE

In 1880 the Ojibway of Minnesota resided on reservations scattered across the northern half of the state as a result of treaties that sanctioned the forced taking of their homelands. The major lakes that comprised the Headwaters of the Mississippi -- Winnibigoshish, Leech, Pokegama, Sandy and Gull -- had been the sites of Ojibway villages since the early 1700s. These waters had also provided the primary means of subsistence for the Headwaters bands, whose culture was intimately bound to the lakes and their associated resources. The bands' yearly cycle revolved around seasonal variations in the bounty provided by the lakes and surrounding woods.

In early spring the women gathered maple sap while the men hunted; in the late spring they planted corn and potatoes. During the summer, people fished, picked berries, collected birch bark for canoes and wigwams, maintained their gardens, and wove mats from lake rushes; in late summer they harvested and processed wild rice. In the fall, band members picked and dried cranberries; and during the winter the men left the villages to hunt and trap. The indigenous wild rice provided the Ojibwe with one of their principle staples. They ate the grain year-round as a side dish, a filler in soups and stews, a snack, and as a main course. In lean times, especially during the long winter, wild rice was often the only food the bands had to eat. To the Ojibwe, the grain also possessed religious significance; they employed it as a ceremonial and ritual food, as well as for medicinal purposes, and made wild rice the subject of their legends. Life around the lakes defined the world of the headwaters bands, including beliefs, ceremonies, superstitions, and social activities. Their landscape was the woods and hay fields of the lakeshore, the wild rice marshes, cranberry bogs, and fishing shoals of the lake. Their pathways ran between and around the lakes and from them to their hunting grounds.

The location, as well as the existence of these water resources was integral to the Ojibwe culture. The reservoirs created by the federal government permanently altered the landscape around the Headwaters lakes and destroyed a significant portion of the bands' means of subsistence. The following chart illustrates the dramatic loss of lake-front property following the construction of the federal dams.

Reservoir	**River**	**Original Lake Area (sq. mi.)**	**Current Lake Area (sq. mi.)**	
Winnibigoshish	Mississippi	117	179	1881
Leech Lake	Leech	173	251	1882
Pokegama	Mississippi	24	35	1882
Sandy Lake	Sandy	8	17	1891
Pine River	Pine	18	24	1883
Gull Lake	Gull	20	21	1911

Source: Cultural Resource Investigation of the Reservoir Shorelines by Elden Johnson (June 1979)

Additionally, the Corps operated the reservoirs in the late 19th and early 20th centuries primarily to improve navigation, and these operations led to frequent changes in lake levels, fluctuations that were devastating to Ojibwe resources. The reservoir system not only severely damaged the Ojibwe economy, but also undermined their traditional way of life.

THE CONTROVERSY OVER COMPENSATION FOR THE TRIBES

The headwaters Ojibwe had been relatively secure in their way of life since the mid-19th Century. An 1855 treaty created reservations for them at Winnibigoshish, Leech, Pokegama, Sandy and Gull Lakes. Under an 1863 treaty, the Ojibwe gave up the reservations at Gull, Sandy, and Pokegama in exchange for a single larger reservation surrounding Cass, Leech, and Winnibigoshish, but discontent with the 1863 treaty led the bands to remain on the old reservations. The next year the Ojibwe negotiated another treaty with the United States, which added a great deal of land to the Leech Lake Reservation and provided that the bands could stay on the 1855 reservations until the government made specific improvements at Leech Lake. Although the improvements were made, few Indians moved from the old reservations.

In the treaty of 1867, the Ojibway ceded their right to the expanded Leech Lake reservation granted in 1864, retaining lands adjoining Cass, Winnibigoshish, and Leech lakes, and acquiring a new reservation west of the headwaters called White Earth. The Mississippi band, whose members lived at Sandy, Pokegama, and Gull lakes, agreed to vacate its reservations, but while some of the band moved to White Earth, many did not. By 1872 only about 550 members out of an estimated total of 2,166 in the Mississippi band had moved. In 1873 President Ulysses S. Grant, by executive order, added White Oak Point to the 1867 reservation that surrounded Winnibigoshish and Leech lakes. White Oak Point was a peninsula in the Mississippi River between Winnibigoshish and Pokegama where the easternmost members of the Mississippi band had been living since 1867. By 1880 the largest concentration of the headwaters bands were at Leech Lake, Lake Winnibigoshish, White Oak Point, and White Earth, although smaller groups remained at the sites of the 1855 reservations until the end of the 19th Century. Government records reveal that in 1889, for example, there were still 277 of the Mississippi band living at Gull Lake.

embroiled in controversy with the tribe, and as the out-of-court settlement of 1985 indicated, the reservoirs project remained a source of controversy between the Minnesota Ojibwe and the federal government for over a hundred years.

Congress approved the construction of the dam at Lake Winnibigoshish in 1880 without regard to the reality that the proposed dams there and at Leech Lake were located on the reservation lands, a fact that raised legal questions about the government's right to take and overflow Ojibwe land. The Corps of Engineers could not begin work until that right to construct the dams and maintain the reservoirs had been established. Therefore, Secretary of War Alexander Ramsey requested an opinion from United States Attorney General Charles Devens. The attorney general concluded that, while the federal government had the power to take the reservation land under the legal doctrine of eminent domain, Congress had failed to exercise that power in the act of June 14, 1880. A proviso attached to the act had stated that "all injuries occasioned by individuals by overflow of their lands shall be ascertained and determined by agreement, or in accordance with the laws of Minnesota, and shall not exceed in aggregate five thousand dollars."

Devens asserted that this proviso could not be extended to Ojibwe tribal land because its language touched only upon individual property owners; there was no propriety in following state law in the matter, since the federal government had jurisdiction over Indian land; and because the proviso limited the amount that could be paid for damages. Since the Corps of Engineers reported that the amount of damages resulting from the Winnibigoshish Dam would exceed the entire sum of money originally appropriated for the project, limiting the amount of damages to $5,000 would amount to taking the tribe's land without just compensation. Devens concluded that Congress could not have intended to dispossess the Ojibwe unfairly. He suggested further legislation was necessary before the government could proceed with the project.

Congress appropriated additional funds on March 3, 1881, for the headwaters reservoirs and provided that the damages paid to the Ojibway should not exceed ten percent of the total amount of money appropriated up to that time. Since this sum equaled $225,000, this proviso again limited the compensation that could be paid to the tribe, this time to the sum of $22,500. Under the assumption that the 1881 legislation had addressed the legal issue of fair compensation, the government appointed a three-man commission in August of that year with a mission to assess the damages that would result from the two dams at Winnibigoshish and Leech lakes. The commission recommended an award of $15,466.90, which the Department of the Interior approved. Consequently, the Corps of Engineers resumed the construction of the Winnibigoshish Dam, which had been suspended pending settlement of the legal questions surrounding the project.

The Ojibwe, however, were far from satisfied. The tribe was so angry about the paltry award recommended that its members refused to accept the money. The degree of dissatisfaction and unrest was so great that Commissioner of Indian Affairs Hiram Price feared an uprising. Friends of the tribe, including Episcopal Bishop Henry B. Whipple and politician Henry M. Rice, persuaded the Ojibwe to keep the peace and not interfere with dam construction in the hope that the authorities would reconsider the award and provide more just compensation. Other prominent Minnesotans, including Henry Hastings Sibley, joined Whipple and Rice in pressuring the federal government to appoint a second commission to reassess the amount of damages done to the tribe.

Bishop Whipple, who had served as a missionary to both the Dakota and Ojibway for many years, was most active on the behalf of Indians in the reservoir controversy. During the fall of 1881, Whipple counseled the irate Ojibway to remain calm while he lobbied Commissioner Price to reopen the compensation matter. At the request of Whipple, White Cloud, an Ojibway chief living at the White Earth Reservation, wrote a letter to the leader of the Pillagers, Flatmouth. White Cloud advised Flatmouth to prevent his followers from sabotaging the dam project until the matter "is satisfactorily settled with the Great Father." White cloud noted that the white friends of the Ojibway were working to change the situation and were concerned about the tribe's welfare.

Dissatisfaction among the Ojibway continued to mount as 1881 became 1882 and still the government had taken no action. Indian resentment and anger grew to such an extent by spring that observers and friends feared that an uprising was imminent. By June 1882, the Ojibway began to fear that the government would never reconsider the matter of the dams, and a consensus was building that the Great Father intended to cheat them out of fair compensation. Many were worried that, having refused the initial award, the tribe would be left with nothing. White Cloud suggested to Whipple that the work on the dams be stopped until the matter was settled. The chief pointed out that the Ojibway had been waiting all winter and spring for a delegation of their leaders to be called to Washington, but to no avail. A sense of panic was developing because tribe members could see the dams being built that would destroy their means of subsistence. White Cloud and his people believed that earlier treaties should protect their reservation land from being taken: "At Washington is an understanding, a strong one, in which a mention is made of our reservations . . . also that a white man should take nothing from those reservations . . . We understood that if the Great Father wished to take anything himself that there would first be an understanding . . . We could and did not give assent to the damming of the river."

In Response to Bishop Whipple and other friends of the Ojibwe, as well as in recognition of the degree of unrest among the headwater bands, Commissioner Price appointed a second commission in December 1882, consisting of Henry Sibley, former Minnesota governor William R. Marshall, and the Episcopal missionary Joseph A. Gilfillan. Price directed the three men to ascertain how much wild rice the Leech Lake Reservation harvested yearly in order to place a cash value on the crop. Similar information was to be gathered about the harvest of cranberries, hay, fish, and maple sap.

Despite the sincere intentions of the second commission to deal quickly and fairly with the Ojibwe, the serious and protracted illness of Sibley, along with other delays, prolonged the commission's work for nine months. Finally, Robert Blakely replaced Sibley late in the summer of 1883. Before the commission submitted its final report in November, Marshall wrote a letter to Price suggesting that the government consider additional compensation to the Ojibwe for "sentimental damage." Marshall explained that there was more at stake for the headwater bands than could be assessed simply in monetary terms:

> As a question of material damage it is not easy to get at a just estimate. I doubt if any commission could arrive at it. The possessions of the Indians, the fishing privileges, rice marshes, sugar-making and canoe-making grounds, etc., have not a marketable and commercial value, such as the possessions and privileges of white men. There is, too, a large sentimental damage, not material, but not less real, involved. Their accustomed haunts are broken up, their paths, roads submerged, they will feel compelled to relocate their villages, will have to adapt themselves to new surroundings, a thing a white man could readily do, but not an Indian.

The commissioner did not respond and also refused requests by Marshall, Sibley, Whipple, and the Ojibwe that a delegation of Indian leaders be brought to Washington to negotiate a settlement. Price insisted that there was no money available to finance a delegation; moreover, he argued, there was no point in meeting until a second commission finished its work. In August the Pillager band wrote Price directly, demanding "not to have built any dams until we have settled with you on our rights." Price responded that nothing could be done until the second commission submitted its report.

As the summer ended, the second commission still had not met with the bands on the Leech Lake Reservation to assess damages. By this time, Bishop Whipple, frustrated and angry over the inaction of the government and the commission, wrote to Price that he was "heart sick" over the entire matter, saying "it is one of the many instances where we have clearly violated principles of justice."

impossible to reach any “reasonable agreement” with the Ojibway as to dollar amounts for the harm that would be done to the bands because they were determined “not to give any information” on their harvests. When the commissioners asked the cash value of the annual harvest of lake resources, the Indians refused to cooperate because they had already decided among themselves to insist upon a biennial award of $250,000. Adamant about this amount, the Ojibwe had agreed to stand firm against any attempts to give them less. Repeatedly during the course of the council at Leech Lake, the various spokesmen for the bands asserted this position and declared their willingness to compromise. They also tried to express to the commission the difficulty of reducing their losses to dollar amounts. One of the most outspoken Pillagers, Sturgeon Man, questioned the ability of the white commission to comprehend what his people would suffer:

> No white man knows of the damage that will be done to us. As long as the sun shall pass over our heads we would have been able to live here if this dam had not been commenced. Every year what supports us grows on this place. If this dam is built we will all be scattered, we will have nothing to live on.

In the end, the commission made its own assessment of damages without the help of the Ojibwe. It predicted, based upon reports of the Corps of Engineers, that the dams would flood 46,920 acres at Lake Winnibigoshish and Leech Lake. The commission, accounting for loses of subsistence and damage to property, recommended a one-time payment of $10,038.18 for properties ruined and an annual payment of $26,800 to compensate for loss of wild rice, berries, maple trees, hay, and fish.

The commission did not, however, pay the Ojibway for the land occupied by the Corps of Engineers for the construction and maintenance of the dams or for the land overflowed by the reservoirs. Legally, the Indians did not own the reservation in fee simple; like other American Indians, they simply had a right to occupy the reservation while the federal government retained title to the land. Under the law, the United States was not obliged to pay because, technically, it owned the property. Even so, the injustice of failing to compensate the Ojibwe for lost reservation land was clear to both the second commission and the commissioner of Indian Affairs. The commission tried to assuage the injustice by being liberal in its estimates of damages to the bands’ subsistence. Price explained in his report to Congress that: “The estimate of the commission for annual damages for rice at 10 cents per pound, and hay at $28 per ton, would appear at first sight to be rather extravagant; but when we consider that over 46,000 acres were taken from the Indians without any compensation whatever, it is believed that the estimate is not too high.”

Price went on to recommend that the one-time payment and the first annuity be paid together as he doubted that the Ojibwe would accept the

$10,038.18 award alone since they had already rejected the first commission's sum of $15,446.90. But the legislation of 1880 and 1881 authorizing construction of the dams had not included provisions for the payment of annual damages to the Ojibway. Thus a new appropriation would be necessary to establish the annuity of $26,800. Unfortunately for the Ojibway, Congress failed to take action and no annuity was ever paid. To make matters worse for the headwater bands, Commissioner Price, reluctant to add insult to injury by offering the $10,038.18, declined to give any money at all to the tribe. Three years later, the Ojibway had still not been compensated.

Despite their apparent ineffectiveness, commission continued to go to the headwaters region to negotiate with the Ojibway. The government appointed a third delegation in 1886 that failed to resolve the dispute and a fourth in 1889, which made some progress. Led by Henry Rice, the fourth commission met with councils at both Leech and Winnibigoshish to ascertain their condition. The bands at Leech, Winnibigoshish, and Cass lakes claimed to be destitute as a result of the reservoirs. Mah-ge-gah-bow, a Pillager spokesman, said that the lake had been "spoilt" by the dams and:

> That is the reason we are compelled to dig snake-root sometimes for subsistence. If it had not been for the action of the whites in stopping up the rivers with the reservoirs we would not be compelled to do that for subsistence. We thought we had arrived at a time when a settlement for those reservoirs would be made; something of a sufficiency to support us; that is the idea we still entertain. And, my friend [to Rice], you are the one who told us to keep quiet and live in peace, and that is why we have; but we see that those dams are conquering us. If you had not spoken to us we would have opened those dams long ago.

At the Lake Winnibigoshish council, the band reported that its cemeteries had been overflowed and that a large number of graves had washed away. Skulls and bones lay scattered along the lakeshore. Their gardens had been ruined and village destroyed; the lakeshore had been made barren by overflow. The outcome of Rice's fourth commission was the recommendation that the headwater bands be paid the $150,000.

Finally, after years of delay, Congress appropriated the $150,000, although it did not provide any money to compensate the Ojibwe for lost land. Also, rather than paying the full amount of the award immediately as the tribe had anticipated, the government disbursed the money over a 34-year period and, in the end failed to pay the entire sum.

The Ojibwe retained the conviction that the 1890 award was grossly inadequate for the irreparable harm done to their resources and way of life. Many years later the Indians' persistent demand for fair compensation led them to challenge the government in court; and in September 1985 the United States government, in an out-of-court settlement, agreed to pay the Leech Lake band $3,390,288 for tribal land taken from them a hundred years earlier. The land had either been confiscated or overflowed as part of a federal project to construct and maintain a system of dams and reservoirs at the major lakes that comprised the headwaters of the Mississippi River. The 1985 settlement pertained to the estimated loss of 178,000 acres of land and damages sustained by the three Ojibway bands living in the vicinity of Lake Winnibigoshish, Leech Lake, and Lake Pokegama.

CONCLUSION

In the first half of the 20th Century, the Corps of Engineers' policy in maintaining the Mississippi headwaters reservoirs remained primarily one of facilitating navigation on the upper Mississippi River. Consequently, the question of damages to Ojibwe land and resources resulting from the construction and maintenance of the dams was not of major concern. Once the locks and dams on the Mississippi abrogated that navigational role of the reservoirs, however, policy changed. Since World War II, the Corps has become increasingly attentive to the effects of reservoir levels on Ojibwe lands and resources. Today, it attempts to manage the headwaters reservoirs to enhance wild rice production, fish and game habitat, and recreation.

The original construction of the dams and the consequential flooding and destruction of tribal lands in conjunction with the inadequate compensation for these losses greatly affected the Ojibwe people. The affects of this are still being felt today, and this history has not been and likely never will be forgotten by the Ojibwe people. Under the ROPE Study, the Corps and the Service have made a determined effort to work cooperatively with the tribe and have done so successfully with representatives of the Leech Lake and Mille Lacs Bands of Ojibwe. Many of the changes proposed in the new plan are a result of this coordination and while it is recognized that these changes will not rectify past injustices, it is hoped that they will benefit the resources important to tribal life.