Norman H. Bangerter
Governor
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State of Utah

DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
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January 7, 1991

REPORT OF MEETING

To: File

From: Gary E. Christenson (reviewed by Susan Olig, Suzanne Hecker, Craig Nelson, Sue Nava, and Jim Tingey)

Subject: Earthquake predictions by Terry Wirth

On December 13, 1990, a meeting was held at CEM to discuss recent earthquake "predictions" made by Terry Wirth in letters sent to Governor Bangerter and the Salt Lake County Commission. The meeting was set up in response to a letter from the Governor (drafted by UGMS) to Terry Wirth requesting that he contact UGMS to discuss his predictions. Persons in attendance at the meeting were Gary Christenson, Susan Olig, and Suzanne Hecker (UGMS); Sue Nava (UUSS); Craig Nelson (Salt Lake County); Jim Tingey (CEM); and Mr. Wirth. Mr. Wirth's background is in geography at the University of Utah. We did not establish whether or not he had undergraduate or graduate degrees, however, or the extent of his work experience.

Brief Summary of Prediction Methods

Mr. Wirth discussed the four factors used in his predictions -Great Salt Lake levels and 3 planetary cycles which affect tides (and also climate, according to Mr. Wirth). He identified these cycles as the harmonic (14.2 yr), anomalistic (19 yr), and ecliptic (18 yr) cycles. He admitted that tectonic forces also cause earthquakes, but does not consider these in his predictions. He has plotted time vs. the three cycles (using a program for planetary cycle information from the U.S. Naval Observatory), historical Great Salt Lake levels, and earthquakes greater than magnitude 4 (attached), and believes he can account for 90% of the earthquakes in basin areas in northwestern Utah (north of the Tooele/Juab County line to the Idaho line and west of the Wasatch Front to the Nevada line). He only uses earthquakes with epicenters below the Bonneville shoreline (mostly in valleys) because he believes the earthquakes are caused by compression and rebound of the basins in response to loading and unloading by water accompanying lake level changes. He believes the gravitational forces associated with the planetary cycles trigger the events when the lake is at certain critical levels.

In plotting earthquakes vs. lake levels, he found that since about 1900 most earthquakes have occurred when the lake was either between 4201-3 or 4195-8 ft. As a result, he considers these to be trigger levels for earthquakes and that future earthquakes are much more likely when the lake is at one of these levels. He considers the earthquakes to be associated more with rebound as the lake level is dropping than with compression during lake level rise, and this is why he believes the earthquake probability to be high in early 1991. The lake has recently dropped below 4203 ft.

Mr. Wirth has assigned monthly probabilities for an earthquake in 1990 and 1991 (see table). The basis for these values was not clear from his explanation. He believes the probabilities to run on a two-year cycle, and has begun the latest cycle in January, 1990. If the lake level is below 4203 (within one of the trigger levels), he considers the monthly probabilities to be additive, and adds each month's probability to the previous month's total to determine the new probability (unless the month has 0% probability, in which case it remains 0%).

Evaluation

In general, Mr. Wirth's presentation was too unclear and incomplete for us to fully understand his methods. We were not in a position to evaluate his work with planetary cycles, except to note that no consistent positive correlation between solid earth tides and earthquakes has yet been shown. His plots of earthquakes vs. the various planetary cycles (he wasn't sure whether he plotted cyclical highs or lows) wasn't graphically convincing. Most earthquakes appear to coincide with the two lake level ranges, although an analysis of the temporal clustering of earthquakes, the percent of total time the lake was at these levels, and his selection of earthquakes needs to be done. The basis for his table of monthly probabilities for 1990-1991, and his use of the table to sum probabilities, were also unclear, and may not be statistically sound.

Arabasz and others (1987) estimate the average return period for a magnitude 4.0 or greater earthquake along the Wasatch Front, an area larger and more seismically active than Wirth's area, to be 2 years. The random probability of an earthquake in this Wasatch Front area each month would be about 4% (based on an average recurrence of 1 every 24 months), and presumably it would be less in Mr. Wirth's area. However, Mr. Wirth's monthly probabilities range from 0-15%, and his additive monthly probabilities up to the end of 1992 range up to 97%. Mr. Wirth might claim success if an earthquake were to occur in a basin area during a month assigned a probability greater than 0% (the next one is March, 1991; 70% of months have >0% probability), when the lake is at one of his preferred levels. However, this is not an unlikely set of circumstances, and such an occurrence would not necessarily validate his method.

In summary, there may be potential problems with his assumed earthquake model, his use of the earthquake catalog, and his statistical methods. We cannot evaluate his treatment of the planetary cycle data, except to say that we do not see how it is incorporated into his predictions. We can neither confirm nor discount his claimed correlations between planetary cycles, lake levels, and earthquakes without considerable additional effort on both his and our part.

At the conclusion of the meeting, we inquired as to his purpose in writing letters to the Governor and Salt Lake County Commission rather than working with the scientific community to refine the method. He replied that he knew them and not us, and that he was merely supplying information. He believes that his methods are still in the experimental stage, and that he will be evaluating his predictive success and back-fitting his model in the future to better fit what really happens. It did not appear that he planned to inform the media of his predictions.

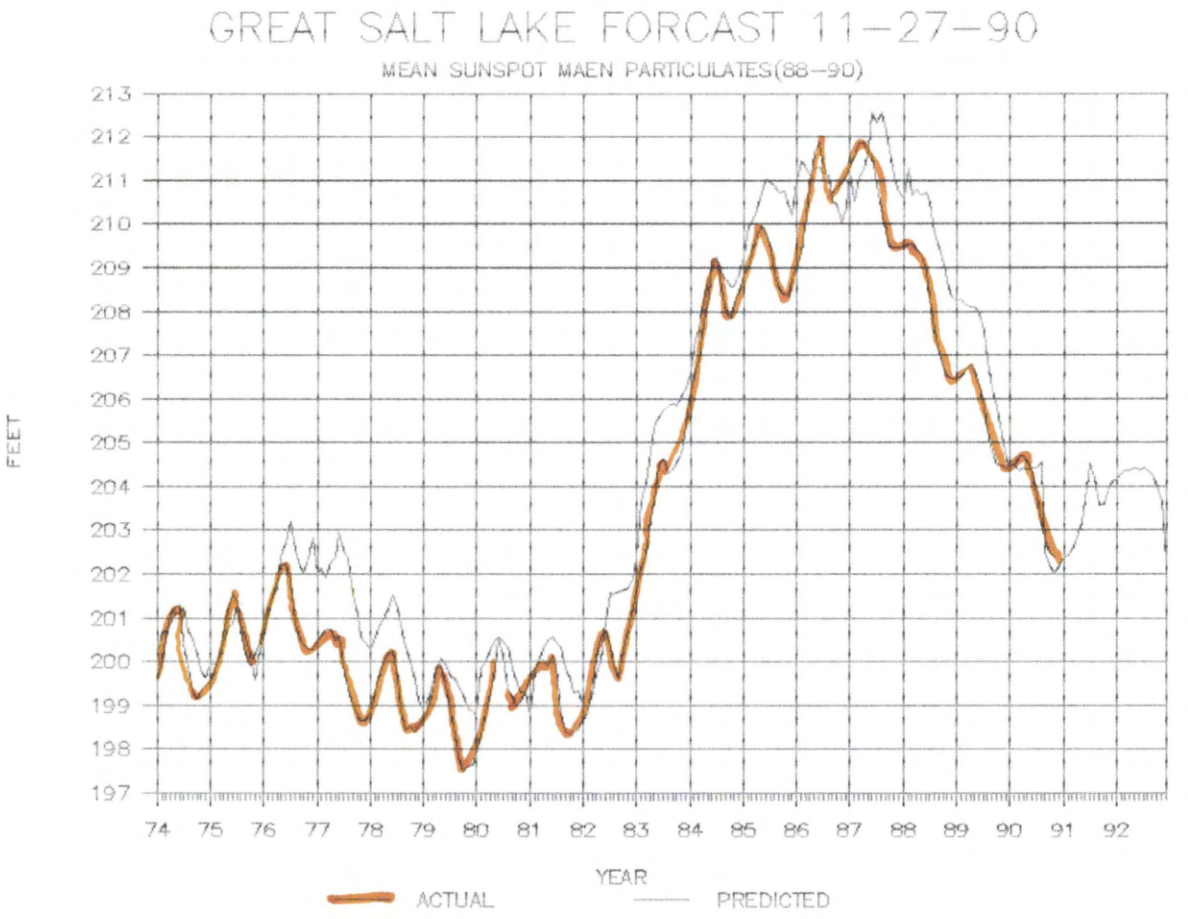
Finally, we indicated that it was hard to evaluate his methodology unless it was clearly documented in writing. We urged him to attempt to publish it in a technical journal, both so that his "predictions" would be in print and so his ideas could be subjected to scientific peer review. We offered to review the paper for him prior to submittal if he so desired.

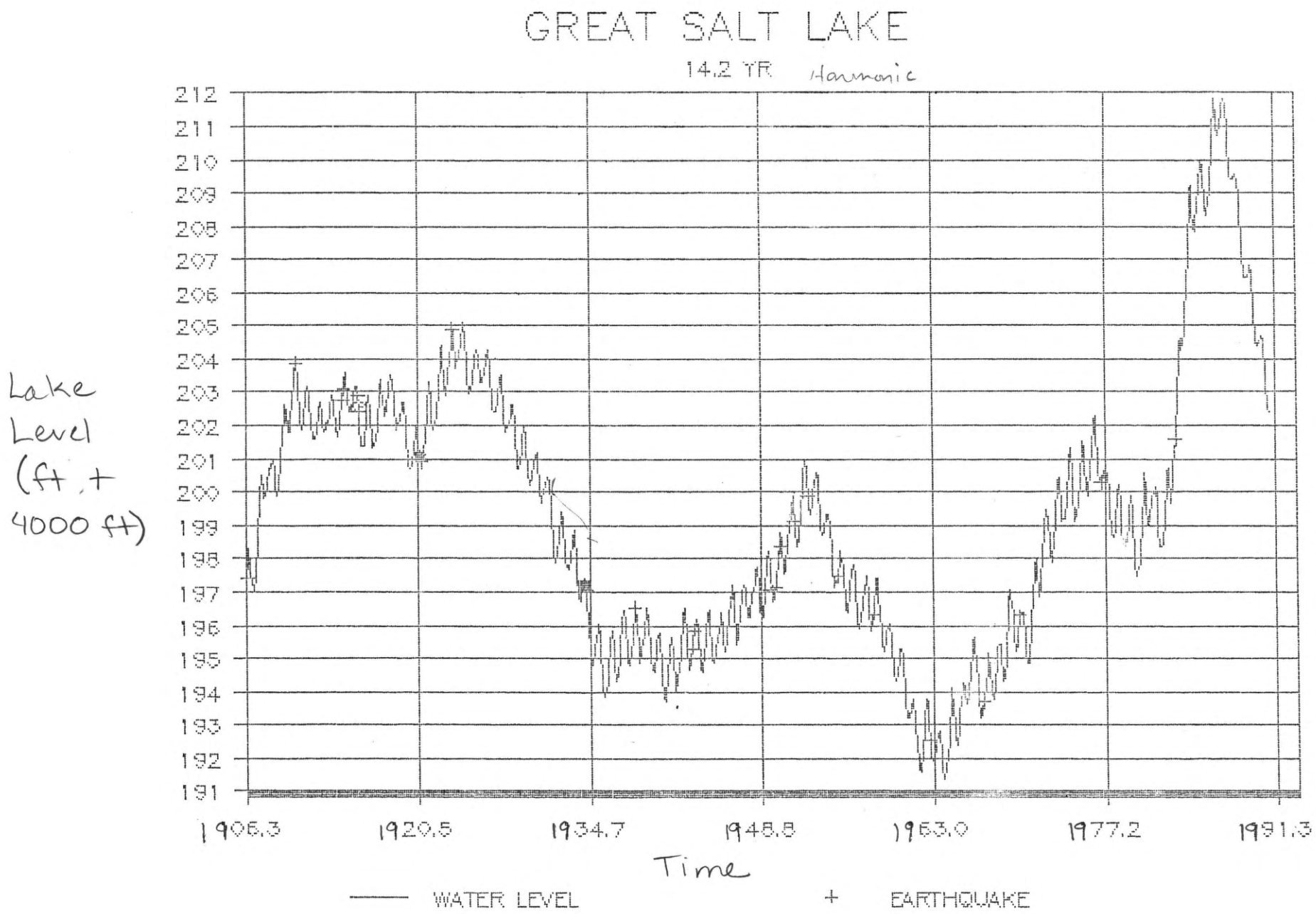
Recommended Action

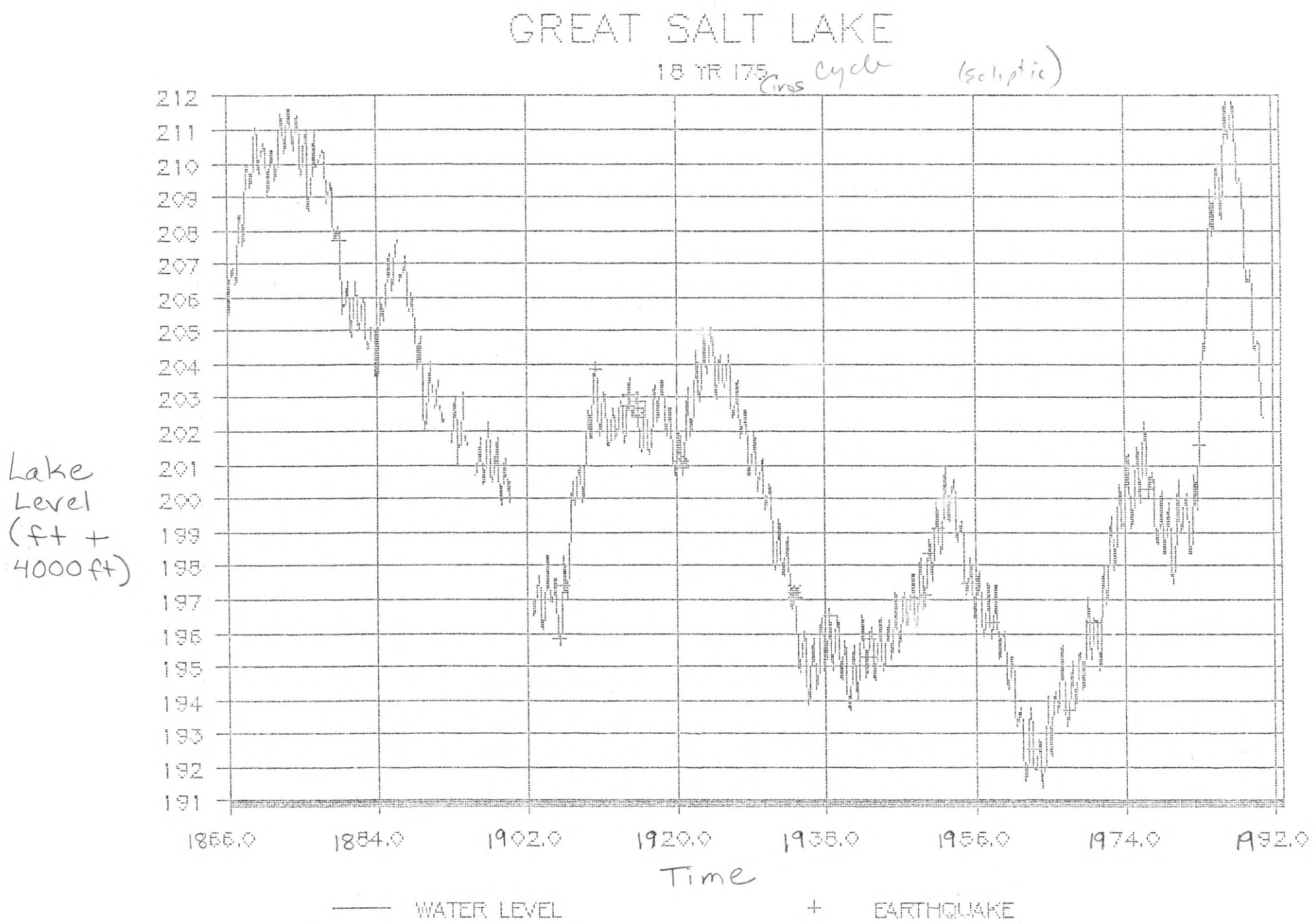
We don't believe any follow-up action is necessary on our part. It does not appear that Mr. Wirth will continue to write letters to the Governor, but rather will look for confirmation and

refinement of his methods as earthquakes occur (or don't occur). We can keep track of his future "success" (through 1991) with the materials he left with us. However, given Utah's rates of seismicity it may take many years to "validate" his method, if it's even possible. We're not sure whether he will take our suggestion and document his methods in writing for scientific review, at least in the near future, until he gets more confident of his predictions. However, we believe that such documentation is necessary before we or anyone else can adequately review the scientific validity of his methods. Pending receipt of such documentation, we do not believe that his predictions deserve further consideration at this time. We will track his "prediction" record based on the material he supplied us.

The idea that Great Salt Lake levels may in some way effect earthquake occurrence is one that may merit a separate and independent study, however. Mr. Wirth's evaluation is not adequate because his methods and statistical treatment are suspect and the earthquake data set and area used are inappropriate. Also, other parameters such as focal depths and mechanisms should be considered to understand the nature of the earthquakes and how it may relate to lake loading.


GREAT SALT LAKE FORCAST 11-27-90
MEAN SUNSPOT MAEN PARTICULATES(88-90)
FEET
213
212
211
210
209
208
207
206
205
204
203
202
201
200
199
198
197
74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
YEAR
ACTUAL
PREDICTED


GREAT SALT LAKE
14.2 YR Harmonic
212
211
210
209
208
207
206
205
204
203
202
201
200
199
198
197
196
195
194
193
192
191
Lake Level (ft. + 4000 ft)
1906.3
1920.5
1934.7
1948.8
1963.0
1977.2
1991.3
Time
WATER LEVEL
+ EARTHQUAKE


GREAT SALT LAKE
18 YR 175 Cycle (Ecliptic)
212
211
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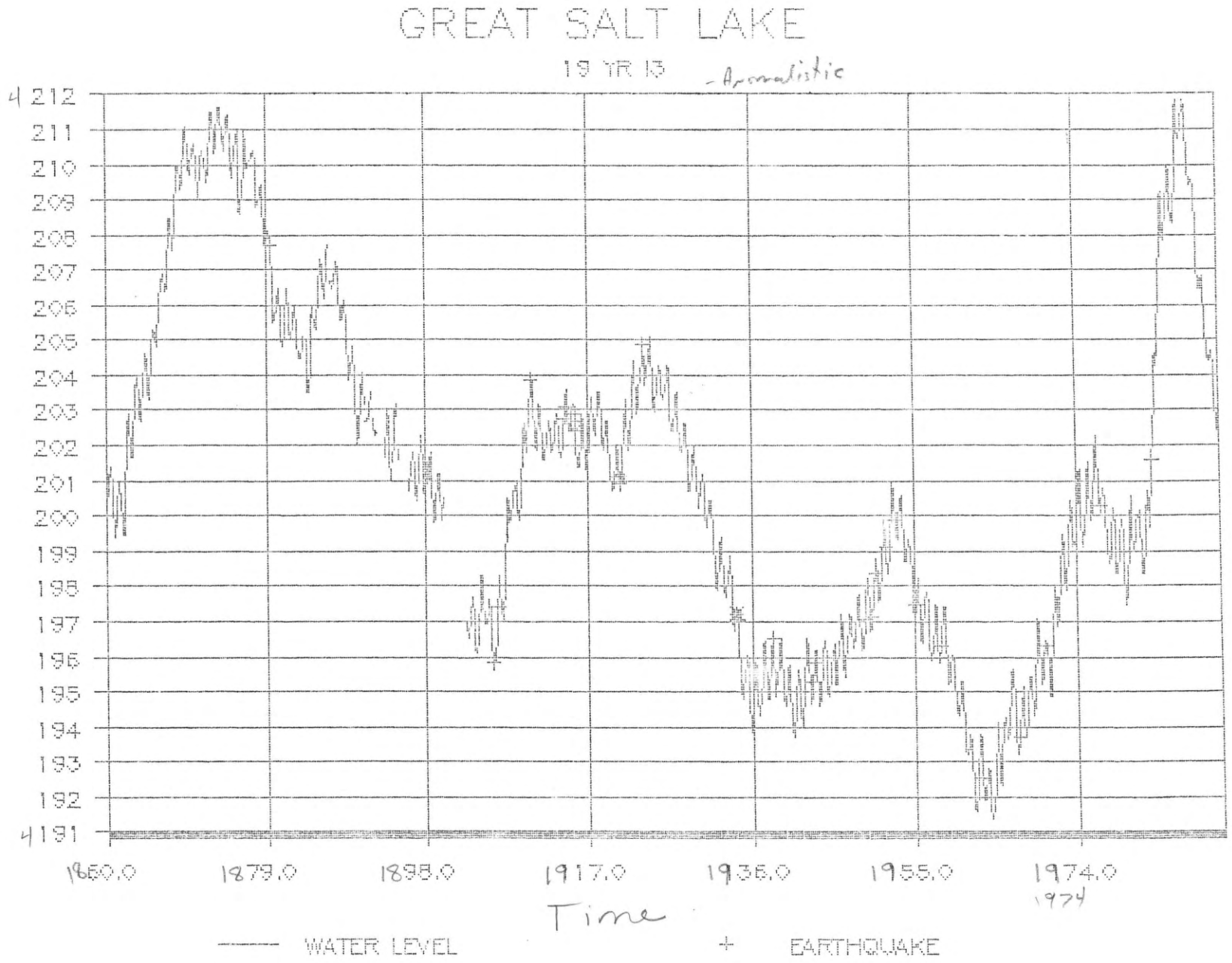
206
205
204
203
202
201
200
199
198
197
196
195
194
193
192
191
Lake Level (ft + 4000 ft)
1856.0
1884.0
1902.0
1920.0
1938.0
1956.0
1974.0
1992.0
Time
WATER LEVEL
+ EARTHQUAKE


GREAT SALT LAKE
19 YR 13 - Anomalistic
4212
211
210
209
208
207
206
205
204
203
202
201
200
199
198
197
196
195
194
193
192
4191
Lake Level (ft + 4000 ft)
1860.0
1879.0
1898.0
1917.0
1936.0
1955.0
1974.0
1974
Time
WATER LEVEL
+ EARTHQUAKE

A PREDICTIVE MODEL FOR EARTHQUAKES IN THE GREAT SALT LAKE BASIN

This forecast is experimental and has not been verified by the forecast of an actual occurrence. It is based on best fit time and place modeling of the geophysical forces of centricity relative to the Salt Lake Basin and surface compression correlation.

The model assumes that the major geophysical forces of gravitation and electro-magnatisum, which are known to have specific cycles, act as triggering mechanisms to certain types of earthquakes. The model further assumes, through historic correlations, that the change in the mass of water in the Great Salt Lake causes compression and rebound of the basin floor. The mass compression by rising lake waters stores energy in the substrata beneath the basin floor, then as the water reseeds past certain levels, rebound can occur causing moderate earthquakes (magnitude 4.0 to 6.5 under current conditions).

The model produces the following percentages of probability:

PERCENT CHANCE OF A MODERATE EARTHQUAKE
IN THE SALT LAKE BASIN BY MONTH

YEAR	1990	1991
JAN	0%	0%
FEB	0%	0%
MAR	8%	15%
APR	5%	5%
MAY	7%	8%
JUN	2%	0%
JUL	8%	7%
AUG	8%	3%
SEP	10%	2%
OCT	5%	2%
NOV	2%	0%
DEC	0%	0%
Maximum TOTAL	1st Yr. 55% Max.	Two Year 97% Max.

How to read the table. The percent for each month equals the best fit statistical probability of an earthquake for that month. If SEP 1990 = 10 and Great Salt Lake has not been below 4203 feet during the past 2 years then there is a 10% probability or a 1 in 10 chance of an earthquake during September. However, after the lake goes below 4203 ft. of elevation the probability must be calculated from the table by summation of the current months value (M) with the monthly values preceding the current month(m+m+...+n), by the number of months(m) times (1.5~) the Lake has been below 4203 feet of elevation.

$$M+m*1.5=sum(n)$$

If Great Salt Lake has been below 4203 feet for 2 months in SEP 1990 then: m=2, and sum(n)=M+2m*1.5=M+m1+m2+m3, and therefore: 10%Sep+8%Aug+8%Jul+2%Jun = 28% probability of an earthquake greater that 4.0 magnitude during SEP 1990. (Note: If the Lake returns above 4203 ft. then goes back below that level, that time must be subtracted from the time factor for the calculations.)

Hypothesis- Nov. 1983 Terry Wirth

The level of the Great Salt Lake controls compression of the valley floor. The valley floor contains strata which respond to isodynamic pressures created by the lake while between 4195-4198 or 4201-4203 feet above sea level.

Strata underlying Great Salt Lake consist of alternating layers of lime, saline sediments, clay deposits and sand deposits Over time some of these layers harden into limestone, shale, sandstone and saline hardpan. these layers have good adhesion within the thin layers and flexibility over the broad expanse of the basin.

Fluid and viscous fluid flow can be achieved in the layers of unconsolidated material between the cemented layers, in response to isodynamic pressure changes from increasing or decreasing water levels in the Lake. The more brittle layers can squeeze the more fluid aquifers between them under varying lake levels causing floor subsidence or rebound in the lake bottom. When the containment layers fault, areas of isodynamic pressure response can occur that respond to changes in lake level with the generation of seismic waves.

In the initial investigation of possible lake to seismic correlation a plot of lake level from the Utah division of Water Resources was used. Seismic events over 4 magnitude in the valley floor area were then plotted superimposed onto the Hydrograph by time of occurrence. Visual inspection of this time correlation plot revelled that most of these valley floor seismic events occurred during times when the lake was between 4195 to 4198 and 4201 to 4203 feet of elevation. (see Hydrograph)

In the initial study 93% of 4.0 or greater earthquakes in the valley floor occurred during a water cycle year that the lake level was within the range 4194.7 to 4197.7 or 4201 to 4203 feet during a significant part of that year. 87% of 4.0 or greater earthquakes in the Salt Lake Valley floor occurred while the Lake was between the levels 4194.7 to 4197.7 or 4201 to 4203 feet while the lake was within those ranges only 45% of the time.

Only 2 seismic occurrences studied had no connection to these 2 trigger levels of the Lake. A 1880 earthquake when the lake had a level of 4206 and a 1963 event when the lake was close to 4192 feet of elevation. Since the 1963 Quake occurred when the lake was close to the low historical level it could indicate the upper level of a third rebound zone below the 4192 foot level.

2nd draft 11-19-90 tjw

Norman H. Bangerter
Governor's Office
State Of Utah
210 State Capitol
Salt Lake City, Utah 84114

October 8, 1990

Dear Governor Bangerter:

According to the last report on Great Salt Lake from the District Chief, WRD, U.S. Geological Survey the North West bay has been at or below 4203 feet since June 15, 1990. The remainder of the Lake is below 4203 feet recording 4202.6 feet on October 1, 1990. The additive model for earthquake forecasting continues in effect for the North West section of Great Salt Lake Valley. The percent chance of a 4.0 to 6.5 earthquake for October 1990 is 5+10+8+8+2+7+(5*.75)=43.75 percent in the north west sector, western Box Elder County.

The percent chance of a 4.0 to 6.5 earthquake in the remainder of the valley is 5+10+8=23% for the Great Salt Lake Valley area of Tooele, Salt Lake, Davis and Weber (see A PREDICTIVE MODEL FOR EARTHQUAKES IN THE GREAT SALT LAKE BASIN 3-27-90, T.J. Wirth).

With all the Lake's surface in the trigger range the magnitude will begin to move toward the upper limit. Pre-shocks of a lesser magnitude than 4.0 will not diminish the chances for the larger 4.0 to 6.5 magnitude earthquake. A 6.0 to 6.5 magnitude quake in the north west sector can cause damage in all parts of the Basin.

Because water levels of the GSL will be stable in November and during the cold months of December, January and February there will be a lowering of the chance of an earth quake during these months. The cause of GSL Basin earth quakes is compression and rebound of the Lake bed caused by changes in water pressure exerted on the bed of the Lake by the water in the Lake. The change in water level acts as a trigger, when the water level is stable other force changes must be used as the trigger.

Days with highly variable harmonic wave tidal forces could act as a trigger to lake bed rebound during these winter months (i.e. Dec. 1st to Dec. 3rd 1990, however, direct mass change by the addition or removal of great volumes of water to the Lake is a superior trigger mechanism for the Great Salt Lake Basin. I estimate the chance of a Great Salt Lake Basin earth quake for December first to the third to equal 5.5% , November third to the fourth will have less than 3.5% chance of an earth quake. No other significant triggers will be available until spring runoff occurs in March of 1991.

If the Lake remains below 4203 feet and above 4201 feet of elevation through March 1991 the runoff triggered chance of a March 1991 earth quake will be 70% for the GSL north west sector and 48% for the remainder of the GSL basin.

Terry J. Wirth
3276 So. 4610 West
(801) 968-6988

NORMAN H. BANGERTER
GOVERNOR

STATE OF UTAH
OFFICE OF THE GOVERNOR
SALT LAKE CITY
84114

September 4, 1990

Mr. Terry J. Wirth
3276 South 4610 West
West Valley City, Utah 84120

Dear Mr. Wirth:

Thank you for your letter of August 2, 1990, concerning earthquake forecasts for the Wasatch Front area. I forwarded the letter to the Utah Geological and Mineral Survey (UGMS) for comment. Although it was unclear from your letter, they indicated that your forecasts appeared to be derived from a relationship between earthquakes and Great Salt Lake levels. Although "reservoir-induced" seismicity related to filling of reservoirs behind dams is a well-documented phenomenon, a predictive relationship between fluctuations in Great Salt Lake levels and earthquakes has not been demonstrated, and insufficient information was included in your letter for the UGMS to evaluate your forecasts. If you wish to discuss this further, I recommend you contact either the Utah Geological and Mineral Survey or the University of Utah Seismograph Stations.

I appreciate your concern over the earthquake threat in Utah, and let me assure you that the state is aware of the threat and is actively addressing earthquake hazard reduction and emergency preparedness so that we are ready for the event you have forecasted. Earthquake-related issues are being given priority for interim study by the Utah State Legislature, and I have asked the Utah Advisory Council for Intergovernmental Relations to head my adminstration's activities and to work with the legislature on earthquake issues.

Sincerely,

Norman H. Bangerter

Norman H. Bangerter
Governor

NHB/dch/la

Gary E. Christensen
Applied Geology
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, Utah 84108

November 15, 1990

Dear Mr. Christensen:

The Governor's Office has referred me to you suggesting that I give you the opportunity to review the data and technical merit of the earthquake probabilities I have sent to the Governor.

Would you please call me at 968-6988 some time during the next week so we can arrange a time to meet and discuss the possible causes and probabilities of earth quakes in the Great Salt Lake Basin.

Sincerely,

Terry J. Wirth

Terry J. Wirth
Geographer
3276 South 4610 West
West Valley City, Utah 84120
(801) 968-6988