CONSORTIUM TO STUDY TRENDS IN SEISMICITY

Quarterly report:
July 1, 2018 through September 30, 2018

by

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INTRODUCTION

The Kansas Geological Survey's Consortium to Study Trends in Seismicity (CSTS) is a public-private partnership aimed at studying trends in seismicity in Kansas. In 2009, seismicity increased significantly (both in terms of earthquake numbers and magnitude) in the midcontinent and later in Kansas, leading to a need to better define and understand seismicity, particularly related to subsurface fluid disposal. The CSTS operates a seismic network that records and allows accurate location and magnitude estimates of seismicity for both felt earthquakes and especially microseismic events that are hundreds of times smaller than can be routinely identified with previous regional seismic networks.

The CSTS is an alliance of the Kansas Geological Survey (KGS), a research and service division of the University of Kansas with a long history of studying the state's subsurface and seismic issues with members of the state's Class 1 disposal well community. Class 1 wells are used for disposal of municipal and industrial waste and are regulated by the Kansas Department of Health and Environment (KDHE). Membership in the CSTS is voluntary, with a common goal of locating and understanding seismicity, especially microseismicity in proximity to member facilities. The CSTS works to establish the baseline or background seismicity near those facilities and provide a scientific basis for differentiating natural (or tectonic) from induced seismicity.

The following report describes CSTS activities for the third quarter of 2018 (which is also the first quarter of the second year of CSTS operation), including a discussion of membership status; network station installation and operation; earthquakes recorded and identified, and earthquake alerts provided to members; and other activities, especially the CSTS's second annual meeting in Wichita in July 2018. Quarterly reports and an annual report have been provided to members since the Consortium's first meeting in July 2017, as per contractual agreement. This current report includes summaries of seismicity and CSTS activities in the past quarter (July, August, and September of 2018).

STATUS OF MEMBERS

The CSTS was established with a two-tier membership system. For Tier 1 members the CSTS provides equipment, installation, and monitoring of a seismograph station; maintains a catalog of seismic events, updated weekly, with a goal of providing e-mail alerts within 24 hours or less of any earthquakes greater than magnitude 2 within 30 miles of a facility; provides an annual report and quarterly reports of monitoring findings; and hosts an annual meeting at which results are discussed and plans formulated for the coming year. Tier 2 members have access to information related to the general information about the seismicity being studied by the CSTS and can attend the annual meeting, but do not have the right to vote at that meeting. The CSTS currently has eleven Tier 1 members and one Tier 2 member.

STATUS OF NETWORK

The CSTS seismic network consists of twelve stations in Kearny, Ellsworth, Rice, McPherson, Reno, Kiowa, Sedgwick, Butler, and Johnson counties, Kansas (Figure 1). Waveforms for these stations are available for Tier 1 members on the seismic network page of the CSTS website (http://www.kgs.ku.edu/Geophysics/CSTS/index.html). For each of those locations, ambient noise tests were undertaken, identifying noise from nearby highways, trains, pump jacks, and other facilities that might create problems with earthquake analysis. In places where noise and vibrations interfered with a station's response, the station was relocated, mindful to retain sensitivity while improving signal to noise. Many of the existing sites are in cemeteries, on government property, or in other locations where noise levels are likely to be low. In all cases, written agreements with landowners are in place.

Each station consists of a seismic sensor that includes a shallowly buried seismometer (sensing motion polarized in x, y, and z directions) embedded on a concrete platform atop a gravel layer, and a digitizer. Ground motion detected by the seismometer is transmitted back to KGS offices in Lawrence real-time via a cellular modem. That communication system is powered by a solar panel that charges two deep-cycle marine batteries. The footprint for each station is approximately 10 feet by 10 feet. The stations have operated with a better than 98% continuous data stream and within designated operational sensitivity and signal-to-noise ratio.

A station's vital statistics are telemetered back to Lawrence coincident with the seismometer responses. Over the last quarter, a couple stations received a visit to adjust solar panels twisted by the wind or torn from the post by the wind. All issues with station operations were detected immediately and service calls issued to avoid or minimize down time (non-transmitting).

EARTHQUAKE ALERTS, CATALOG

Earthquakes with magnitudes of 2 or larger (some of which may be below felt levels) represent a threshold above which the CSTS network, in conjunction with the KGS regional and subregional networks, can provide highly confident automatic analysis. It is therefore reasonable to provide accurate epicenter locations using automated picking routines for each event at these energy levels, with results available within minutes of the fault rupture. Beginning in September 2018, the CSTS used an automated notification process to inform members of events of M 2 or larger earthquake within 30 miles of Tier 1 member wells. Those notifications provide epicenter latitude and longitude, origin time, and distance from the member well(s).

In the third quarter of the calendar year there were 22 earthquakes that met these criteria (Table 1), about the same as the previous quarter. Microearthquake activity recorded by the KGS and CSTS networks was down relative to the previous quarter. A total of 59 earthquakes ranging from M 1.0 to 2.7 were recorded within 20 miles of member wells (Figure 2, Table 2). Most epicenters are within previously identified clusters or along known trends. Subnetwork activity (Table 3) was similar to the previous quarter, with the exception of events near station RN01. Subnetwork events near RN01 decreased

from more than 250 last quarter to 138 this quarter. Fluctuations are related to changes in the stress field along properly oriented faults, so the decrease is meaningful, but more data will be necessary to begin postulating possible causes for this effect.

OTHER ACTIVITIES

The second annual CSTS meeting was held in Wichita on July 18, 2018. This meeting marked the first anniversary of the Consortium's creation and the first meeting since CSTS became fully operational. Eleven member companies were represented by 20 participants, along with staff from the Kansas Department of Health and Environment (KDHE) and the Kansas Corporation Commission (KCC). The morning session included presentations on national seismicity issues and responses, the Kansas monitoring network, the CSTS monitoring network, recent seismic activity, Arbuckle fluid issues, and an update from the KCC. The afternoon involved extensive discussion among Consortium members about CSTS activities and directions. Presentations from that meeting are available to Tier 1 and Tier 2 members on the CSTS webpage.

In general, members expressed support for continued levels of monitoring and the need for additional seismic data, and had questions about regulatory actions, particularly the different approaches taken between Class 1 and Class 2 wells. There was follow-up conversation about rising fluid levels and pressures in some Arbuckle wells, and about the creation of a working group by the KGS, KCC, and KDHE, along with representatives of the Class 1 and Class 2 communities, to study Arbuckle. Discussion has taken place within that working group and at the CSTS annual meeting about the need for additional pressure/fluid level data and ways to obtain that data. The Arbuckle working group is also exploring a joint meeting with the Oklahoma Corporation Commission and the Oklahoma Geological Survey to discuss Arbuckle issues in Oklahoma.

PLANS

Over the next few months, the KGS will begin a more in-depth examination of microearthquakes too small to uniquely locate with the existing network, but in areas of strategic interest to CSTS members. A potential outcome will be the deployment of a single seismograph station for a few months, ideally located for establishing where on a circle around the station that detected these microearthquakes the culprit fault is located, or at least from which of two possible locations the earthquake originated.

Coming over the next few months will be notable improvements in options for earthquake mapping and listing of event specific information available to Tier 1 members on the CSTS web site. These improvements should provide significant value when comparing reported injection volumes with changes in seismicity in proximity to member facilities. All KGS injection data reported by operators will be accessible.

CONCLUSION

Agreements for the 12 Tier 1 members and the one Tier 2 member are continuing in the second year of the Consortium's operation. The installed stations have operated successfully, and alerts are now being delivered to members automatically as prescribed

under contract. CSTS staff continues to look at methods of providing information based on conversations at the 2018 annual meeting and continues to develop information related to the connection between seismic activity and Arbuckle fluid disposal. To enhance the quality and value of the product the CSTS is delivering to its members, feedback from members is essential and highly valued. Please spend time reviewing CSTS products and providing feedback about improvements to current or additional products.

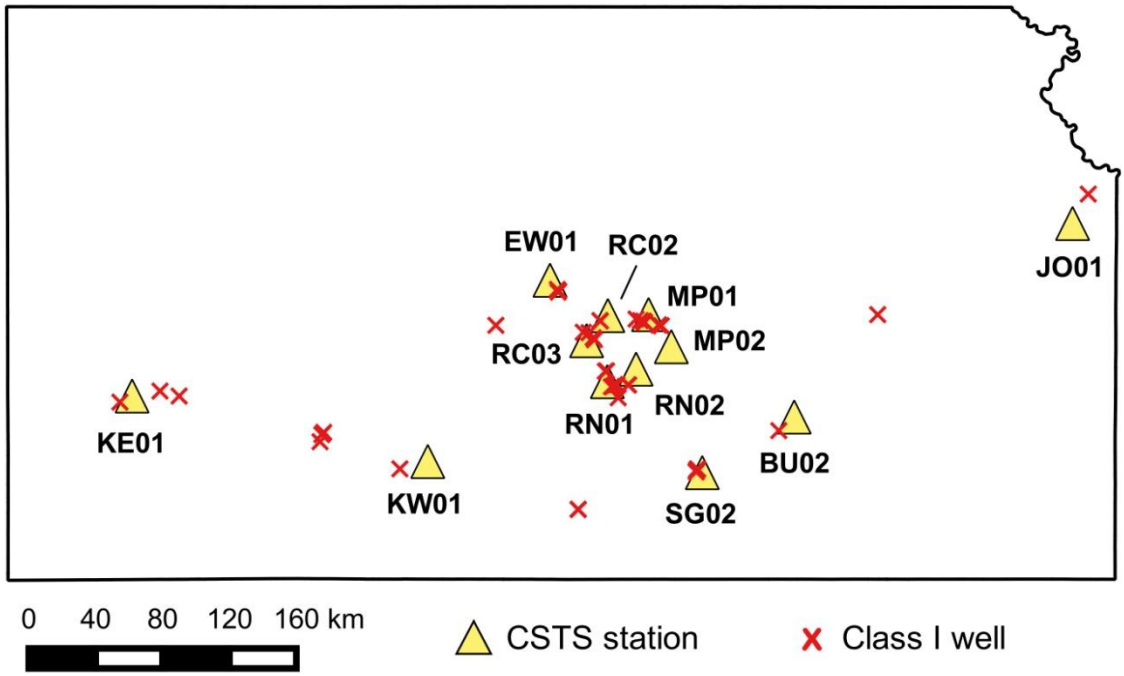

Figure 1. The 12 stations in the current CSTS seismic network.

Table 1. M 2 or larger earthquakes recorded from July 1 through September 30, with epicenters located within 30 mi of Tier 1 member wells.

Origin Time (UTC)	Latitude	Longitude	Magnitude	County
2018-07-23 23:05:06	37.162	-97.612	2.1	Sumner
2018-07-25 18:16:17	38.014	-97.997	2.4	Reno
2018-07-25 18:16:19	38.011	-97.996	2.5	Reno
2018-08-05 01:42:07	38.018	-97.996	2.0	Reno
2018-08-14 15:54:11	38.792	-97.507	2.2	Saline
2018-08-16 11:55:37	38.008	-97.992	2.0	Reno
2018-08-22 17:07:41	37.386	-97.825	2.0	Harper
2018-08-23 16:41:56	38.014	-97.982	2.6	Reno
2018-08-23 16:41:58	38.012	-98.006	2.7	Reno
2018-08-26 06:18:36	37.345	-97.802	2.0	Sumner
2018-08-27 12:40:39	38.645	-97.510	2.3	Saline
2018-08-30 02:49:55	37.353	-97.829	2.0	Harper
2018-09-03 16:02:23	37.348	-97.833	2.6	Harper
2018-09-05 03:21:54	38.011	-97.983	2.3	Reno
2018-09-05 03:21:55	38.014	-98.000	2.5	Reno
2018-09-28 00:51:52	37.172	-97.449	2.4	Sumner
2018-09-29 10:39:48	37.180	-97.452	2.3	Sumner
2018-09-29 18:07:36	37.175	-97.457	3.0	Sumner
2018-09-29 19:25:35	37.182	-97.455	3.0	Sumner
2018-09-29 20:33:53	37.175	-97.438	2.1	Sumner
2018-09-30 08:39:07	37.177	-97.449	2.8	Sumner
2018-09-30 11:09:23	37.183	-97.451	2.3	Sumner

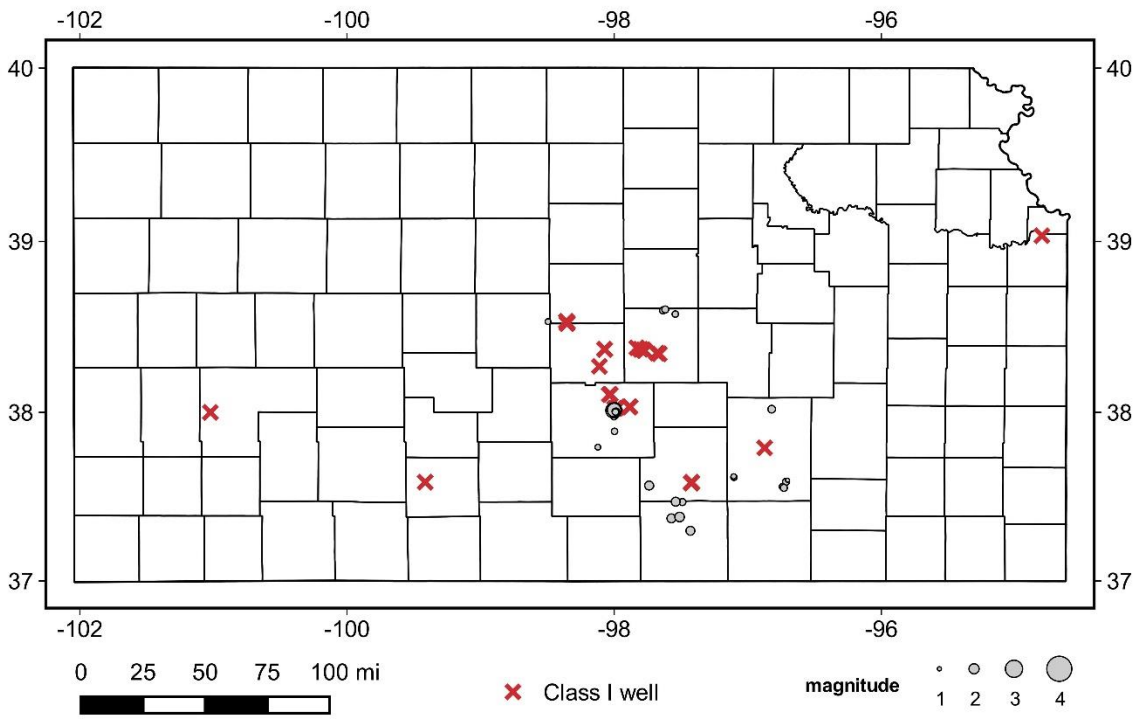

Figure 2. Earthquakes (gray circles) and Class I wells (red Xs) recorded by the KGS and CSTS seismic networks from July 1 to September 30, 2018, located within 20 miles of CSTS member wells.

Table 2. Earthquakes located within 20 miles of member wells.

Origin Time (UTC)	Latitude	Longi-tude	Magni-tude
2018-07-02 19:35:24	37.470	-97.489	1.5
2018-07-05 00:04:05	37.566	-97.732	1.6
2018-07-08 07:28:35	38.599	-97.634	1.5
2018-07-09 12:41:14	38.011	-97.988	1.7
2018-07-10 07:00:52	37.989	-97.980	1.0
2018-07-11 01:34:45	38.022	-97.981	1.9
2018-07-11 08:23:42	38.008	-97.993	1.3
2018-07-12 07:44:43	38.019	-96.820	1.6
2018-07-13 21:04:53	38.015	-97.992	1.6
2018-07-13 21:57:26	38.020	-97.988	1.7
2018-07-14 02:37:17	38.012	-98.004	1.8
2018-07-16 02:38:15	37.991	-97.987	1.1
2018-07-16 05:09:04	38.604	-97.617	1.5
2018-07-16 18:15:20	38.026	-97.991	1.0
2018-07-16 22:39:02	38.015	-97.990	1.7
2018-07-17 06:21:03	37.373	-97.571	1.8
2018-07-17 18:25:22	37.982	-97.990	1.4
2018-07-19 12:07:48	37.299	-97.429	1.8
2018-07-22 15:41:26	38.577	-97.542	1.4
2018-07-25 18:16:19	38.011	-97.996	2.5
2018-07-25 18:22:11	38.018	-97.992	1.6
2018-07-28 04:53:00	38.009	-97.979	1.6
2018-07-31 06:52:13	38.006	-98.002	1.4
2018-08-04 00:48:23	37.998	-98.001	1.6
2018-08-04 01:18:31	37.973	-98.002	1.3
2018-08-05 01:42:07	38.018	-97.996	2.0
2018-08-05 04:01:28	38.007	-97.996	1.7
2018-08-05 04:14:15	38.014	-97.990	1.7
2018-08-07 14:52:21	38.010	-97.992	1.0
2018-08-09 01:07:05	38.033	-97.988	1.7
2018-08-09 15:44:17	37.590	-96.713	1.5
2018-08-09 16:10:15	37.561	-96.740	1.4
2018-08-09 22:29:21	37.554	-96.729	1.5
2018-08-11 11:34:30	37.568	-97.738	1.8
2018-08-14 20:45:01	38.004	-97.989	1.5
2018-08-15 07:13:11	37.795	-98.122	1.3
2018-08-15 20:23:29	38.022	-97.986	1.2
2018-08-16 11:43:28	38.009	-97.979	1.5
2018-08-16 11:55:06	38.008	-97.992	2.0
2018-08-17 18:03:09	37.617	-97.103	1.4
2018-08-22 07:16:01	37.622	-97.105	1.2
2018-08-22 17:52:08	38.022	-97.979	1.8
2018-08-23 02:31:27	38.011	-97.988	1.7
2018-08-23 02:40:20	38.014	-97.996	1.3
2018-08-23 02:41:16	38.035	-97.977	1.2
2018-08-23 08:04:10	37.995	-97.986	1.3
2018-08-23 16:41:27	38.012	-98.006	2.7
2018-08-30 00:30:15	38.007	-97.990	1.5
2018-08-30 00:34:14	38.014	-97.987	1.4
2018-09-01 20:23:01	38.025	-97.987	1.4
2018-09-05 03:21:24	38.014	-98.000	2.5
2018-09-06 10:05:01	37.599	-96.702	1.0
2018-09-07 14:12:09	37.472	-97.539	1.8
2018-09-09 12:20:08	37.888	-97.997	1.4
2018-09-15 02:57:04	37.381	-97.510	1.9
2018-09-18 22:31:16	38.533	-98.495	1.3
2018-09-18 22:52:07	38.005	-97.985	1.5
2018-09-24 08:11:20	38.006	-97.994	1.3
2018-09-27 16:23:20	38.002	-97.990	1.4

Table 3. Possible subnetwork earthquakes from July 1 to September 30, 2018, recorded within 12 miles of member wells (the largest published distance between an induced earthquake swarm and causal well). Epicentral distance is the estimated distance from the earthquake epicenter to the seismic station where it was recorded.

Station	Origin Time (UTC)	Distance (Miles)	Magnitude
BU02	2018-07-01 19:51:35	5.4	0.0
BU02	2018-07-13 09:05:03	10.8	1.2
BU02	2018-08-28 20:28:28	4.8	0.1
MP01	2018-07-01 07:40:45	9.7	1.0
MP01	2018-07-14 01:21:25	8.1	0.4
MP01	2018-07-17 11:03:31	7.7	0.4
MP01	2018-08-21 11:32:35	3.2	0.4
MP02	2018-07-03 20:21:33	2.9	0.0
MP02	2018-07-04 20:09:10	4.5	-0.4
MP02	2018-07-04 22:55:49	5.2	0.3
MP02	2018-07-11 20:55:03	4.1	0.4
MP02	2018-07-16 14:56:04	3.0	0.0
MP02	2018-07-16 15:27:50	2.9	-0.2
MP02	2018-07-17 17:19:34	1.7	-0.2
MP02	2018-07-17 17:53:48	2.8	-0.2
MP02	2018-07-18 20:22:15	3.2	0.1
MP02	2018-07-20 05:21:16	1.8	0.0
MP02	2018-08-24 02:11:11	2.5	-0.2
MP02	2018-08-24 11:39:22	6.9	0.4
MP02	2018-08-25 11:54:47	6.8	0.3
MP02	2018-08-31 21:00:16	1.7	-0.2
MP02	2018-08-31 21:00:16	1.5	-0.6
MP02	2018-08-31 22:08:42	2.2	-0.6
MP02	2018-09-01 02:06:22	1.4	-0.2
MP02	2018-09-02 18:35:36	4.5	0.2
MP02	2018-09-04 10:33:02	2.4	-0.2
MP02	2018-09-04 10:33:02	2.2	-0.2
MP02	2018-09-04 10:35:55	2.9	-0.4
MP02	2018-09-04 11:23:09	1.7	-0.2
MP02	2018-09-05 03:03:37	3.3	0.4
MP02	2018-09-10 23:47:27	2.1	0.0
MP02	2018-09-11 20:48:07	4.1	0.1
MP02	2018-09-13 22:46:22	1.8	-0.6
MP02	2018-09-13 23:18:49	4.3	0.3
RC02	2018-07-07 20:07:00	8.6	0.4
RC02	2018-07-10 03:17:25	2.2	0.1
RC02	2018-09-03 03:53:15	2.9	0.0
RC02	2018-09-30 01:42:05	3.3	0.1
RC03	2018-07-02 10:08:22	7.4	0.6
RC03	2018-07-03 18:00:53	9.7	0.6
RC03	2018-07-03 18:00:53	7.3	0.3
RC03	2018-07-09 10:36:39	7.0	0.9
RC03	2018-07-09 10:36:39	6.6	0.6
RC03	2018-07-10 02:22:46	7.8	0.8
RC03	2018-07-10 11:55:25	7.4	0.7
RC03	2018-07-10 18:19:48	7.4	1.0
RC03	2018-07-11 02:17:59	7.0	0.6
RC03	2018-07-11 02:22:13	7.0	0.5
RC03	2018-07-11 10:14:04	7.0	0.6
RC03	2018-07-11 10:19:34	8.4	0.3
RC03	2018-07-13 02:18:23	6.8	0.6
RC03	2018-07-13 02:19:39	7.2	0.5
RC03	2018-07-14 10:00:49	6.5	0.6
RC03	2018-07-17 13:18:54	4.9	0.1
RC03	2018-07-17 14:09:46	8.7	1.3
RC03	2018-07-18 02:22:43	9.2	0.6
RC03	2018-07-18 18:11:05	7.2	1.2
RC03	2018-07-19 02:17:21	7.9	0.8
RC03	2018-07-19 18:20:22	7.6	0.8
RC03	2018-07-20 10:15:53	7.2	0.8
RC03	2018-07-20 10:17:02	6.7	1.2
RC03	2018-07-21 02:24:31	7.4	0.4
RC03	2018-07-21 10:18:29	6.8	1.2
RC03	2018-07-24 02:18:47	7.4	0.4
RC03	2018-07-24 02:19:18	7.1	0.4
RC03	2018-07-24 10:10:27	7.2	0.5
RC03	2018-07-24 10:11:30	7.5	0.7
RC03	2018-07-25 10:13:23	6.7	0.8
RC03	2018-07-26 02:17:57	7.2	0.1
RC03	2018-07-26 02:18:32	7.4	0.1
RC03	2018-07-27 10:10:54	7.8	0.6
RC03	2018-07-29 02:12:11	8.0	0.8
RC03	2018-08-01 10:24:57	7.8	0.3
RC03	2018-08-01 10:26:05	7.3	0.1
RC03	2018-08-01 18:20:07	7.6	0.7
RC03	2018-08-01 18:20:47	6.7	0.4
RC03	2018-08-02 02:20:26	7.3	0.8
RC03	2018-08-02 18:23:32	7.6	0.3
RC03	2018-08-02 18:24:21	7.5	0.1
RC03	2018-08-07 10:16:27	6.5	0.4
RC03	2018-08-07 18:32:22	8.3	0.5
RC03	2018-08-07 18:32:22	7.5	0.5
RC03	2018-08-07 18:35:13	8.3	0.7
RC03	2018-08-07 18:36:06	7.6	0.4
RC03	2018-08-08 02:16:55	7.6	0.3
RC03	2018-08-08 02:17:54	7.5	0.4
RC03	2018-08-08 02:21:32	8.1	0.3
RC03	2018-08-08 18:16:30	7.3	0.1
RC03	2018-08-08 18:17:14	8.4	0.3
RC03	2018-08-09 02:18:52	7.1	0.3
RC03	2018-08-09 02:19:40	7.3	0.4
RC03	2018-08-09 02:20:53	6.5	0.0
RC03	2018-08-10 10:12:01	7.3	0.4
RC03	2018-08-10 10:13:08	6.8	0.8
RC03	2018-08-12 01:55:08	7.2	0.3
RC03	2018-08-12 01:55:58	6.7	0.3
RC03	2018-08-14 11:42:24	2.6	0.2
RC03	2018-08-17 00:41:03	1.8	0.0
RC03	2018-08-30 02:22:21	8.0	0.8
RC03	2018-08-31 02:20:24	7.1	0.4
RC03	2018-09-01 02:16:15	7.9	0.4
RC03	2018-09-01 02:17:08	7.6	0.7
RC03	2018-09-05 02:21:13	6.8	0.7
RC03	2018-09-05 02:21:59	7.1	0.8
RC03	2018-09-06 02:17:37	7.3	0.4
RC03	2018-09-06 18:35:14	7.4	0.7
RC03	2018-09-07 18:19:25	7.1	0.8
RC03	2018-09-07 18:21:35	7.2	0.7
RC03	2018-09-08 02:17:43	7.2	0.5
RC03	2018-09-08 02:18:32	6.9	0.4
RC03	2018-09-08 18:21:47	7.3	0.7
RC03	2018-09-08 18:22:43	7.8	0.9

Table 3. Continued

Station	Origin Time (UTC)	Distance (Miles)	Magni-tude
RC03	2018-09-10 18:09:24	7.3	0.4
RC03	2018-09-12 10:20:01	7.7	0.7
RC03	2018-09-12 18:21:54	7.0	0.3
RC03	2018-09-13 02:19:59	7.3	0.7
RC03	2018-09-13 03:58:43	7.2	0.2
RC03	2018-09-13 10:15:15	7.6	0.7
RC03	2018-09-16 02:30:57	7.3	0.5
RC03	2018-09-17 10:14:24	7.9	0.1
RC03	2018-09-17 10:14:56	7.0	0.1
RC03	2018-09-18 02:23:16	7.2	-0.2
RC03	2018-09-18 02:23:21	7.4	0.1
RC03	2018-09-18 10:14:10	7.1	0.1
RC03	2018-09-19 10:17:46	7.3	0.3
RC03	2018-09-20 10:19:15	7.2	0.1
RC03	2018-09-20 18:20:28	7.1	0.1
RC03	2018-09-20 18:21:34	7.9	0.2
RC03	2018-09-20 18:22:14	6.9	0.2
RC03	2018-09-21 10:11:15	7.6	0.0
RC03	2018-09-21 10:11:45	7.8	0.4
RC03	2018-09-22 10:07:38	6.8	0.5
RC03	2018-09-22 10:08:12	6.3	0.4
RC03	2018-09-22 10:08:33	6.7	0.2
RC03	2018-09-22 10:10:06	7.8	0.7
RC03	2018-09-22 10:11:56	7.7	0.4
RC03	2018-09-22 11:08:32	4.0	0.2
RC03	2018-09-25 10:21:55	7.2	0.4
RC03	2018-09-25 10:22:27	7.2	0.8
RC03	2018-09-25 18:21:30	7.5	0.1
RC03	2018-09-27 02:17:45	7.9	0.4
RC03	2018-09-27 09:45:04	7.2	0.4
RC03	2018-09-29 10:12:09	7.2	0.7
RC03	2018-09-29 10:13:18	7.1	1.0
RN01	2018-07-01 19:23:38	5.3	0.5
RN01	2018-07-02 08:02:49	4.9	0.1
RN01	2018-07-03 09:47:53	5.5	0.7
RN01	2018-07-07 02:16:21	4.9	0.2
RN01	2018-07-08 03:06:29	4.9	0.0
RN01	2018-07-08 05:49:17	5.0	-0.2
RN01	2018-07-08 06:57:49	4.8	0.3
RN01	2018-07-08 12:40:51	5.0	0.0
RN01	2018-07-08 12:42:06	5.1	0.4
RN01	2018-07-08 12:44:28	4.9	0.1
RN01	2018-07-08 14:02:17	5.0	0.3
RN01	2018-07-08 19:04:24	5.2	1.0
RN01	2018-07-08 21:11:33	5.3	0.0
RN01	2018-07-10 07:02:25	5.1	0.1
RN01	2018-07-10 08:15:04	3.3	0.2
RN01	2018-07-10 08:49:38	4.8	0.4
RN01	2018-07-10 11:04:45	4.9	0.2
RN01	2018-07-11 01:37:34	4.9	0.1
RN01	2018-07-11 01:44:16	4.9	0.3
RN01	2018-07-11 02:05:33	4.9	0.1
RN01	2018-07-11 02:05:59	4.8	0.3
RN01	2018-07-11 03:46:45	4.9	0.2
RN01	2018-07-11 05:20:58	4.7	0.4
RN01	2018-07-11 08:33:39	4.8	0.6
RN01	2018-07-11 08:46:21	4.9	0.4
RN01	2018-07-12 22:11:08	2.2	0.2
RN01	2018-07-13 06:44:50	4.8	0.4
RN01	2018-07-13 22:35:43	5.0	0.6
RN01	2018-07-14 06:31:50	7.7	1.3
RN01	2018-07-14 15:42:08	5.1	0.6
RN01	2018-07-14 19:24:22	5.5	0.2
RN01	2018-07-16 03:25:40	4.5	0.0
RN01	2018-07-16 08:57:36	5.5	0.2
RN01	2018-07-16 18:42:13	5.3	0.3
RN01	2018-07-17 04:03:54	5.2	0.1
RN01	2018-07-17 04:33:58	4.9	0.2
RN01	2018-07-17 05:31:43	5.1	0.3
RN01	2018-07-17 05:33:38	5.0	0.2
RN01	2018-07-18 12:08:22	4.6	0.1
RN01	2018-07-19 07:36:58	2.2	0.1
RN01	2018-07-19 22:36:40	1.8	0.0
RN01	2018-07-19 22:36:40	2.0	-0.2
RN01	2018-07-20 05:23:19	5.0	0.0
RN01	2018-07-20 09:47:19	4.9	0.0
RN01	2018-07-20 10:38:03	4.4	0.1
RN01	2018-07-22 06:56:51	5.1	0.6
RN01	2018-07-22 18:13:57	4.7	-0.2
RN01	2018-07-23 08:58:43	6.1	0.3
RN01	2018-07-24 01:00:13	1.4	-0.9
RN01	2018-07-24 10:12:05	5.7	-0.2
RN01	2018-07-24 13:20:59	4.9	0.5
RN01	2018-07-25 18:27:50	5.2	0.7
RN01	2018-07-25 20:35:37	5.2	0.9
RN01	2018-07-26 02:26:42	4.8	0.7
RN01	2018-07-26 03:52:29	4.6	0.6
RN01	2018-07-26 05:00:29	4.9	0.6
RN01	2018-07-27 05:16:48	5.2	0.2
RN01	2018-07-27 21:48:51	4.6	0.2
RN01	2018-07-27 23:08:48	3.8	0.4
RN01	2018-07-28 18:13:35	4.8	0.0
RN01	2018-07-29 03:54:52	5.4	0.6
RN01	2018-07-30 00:04:31	5.0	0.5
RN01	2018-07-31 18:10:56	4.9	0.4
RN01	2018-08-01 06:51:11	5.0	0.3
RN01	2018-08-01 10:07:28	4.9	0.6
RN01	2018-08-01 11:16:20	4.6	0.2
RN01	2018-08-01 14:30:58	5.2	0.1
RN01	2018-08-02 20:24:54	2.5	0.4
RN01	2018-08-03 04:53:05	5.0	0.4
RN01	2018-08-03 09:37:18	5.1	0.1
RN01	2018-08-03 13:03:29	4.7	0.2
RN01	2018-08-04 00:42:11	5.2	0.3
RN01	2018-08-04 01:18:31	4.9	0.7
RN01	2018-08-04 09:54:22	5.4	0.2
RN01	2018-08-04 11:13:04	5.1	0.0
RN01	2018-08-05 01:45:00	5.0	0.2
RN01	2018-08-05 09:47:26	3.9	0.4
RN01	2018-08-05 12:08:36	5.3	0.4
RN01	2018-08-06 08:31:32	5.7	0.4
RN01	2018-08-06 19:04:13	6.9	0.7
RN01	2018-08-06 23:11:40	5.1	0.1
RN01	2018-08-07 04:06:12	4.7	-0.2
RN01	2018-08-08 09:20:58	4.7	0.0
RN01	2018-08-08 16:03:18	4.9	0.2
RN01	2018-08-09 01:17:53	5.3	0.0
RN01	2018-08-09 04:49:15	4.8	0.6
RN01	2018-08-10 04:54:21	4.3	0.0
RN01	2018-08-10 14:27:45	4.7	0.1

Table 3. Continued

Station	Origin Time (UTC)	Distance (Miles)	Magni-tude
RN01	2018-08-11 01:55:02	4.7	0.2
RN01	2018-08-14 07:16:32	5.1	0.4
RN01	2018-08-14 07:22:11	5.2	0.0
RN01	2018-08-14 17:18:19	4.8	0.2
RN01	2018-08-15 02:02:39	5.0	0.4
RN01	2018-08-15 07:01:24	5.1	0.2
RN01	2018-08-16 18:28:32	4.8	0.0
RN01	2018-08-16 19:46:46	5.1	0.2
RN01	2018-08-17 04:55:46	5.0	0.4
RN01	2018-08-17 23:31:10	4.7	-0.2
RN01	2018-08-18 05:24:12	4.9	0.4
RN01	2018-08-19 04:10:12	5.1	0.0
RN01	2018-08-22 13:53:48	6.0	0.6
RN01	2018-08-23 03:00:04	5.4	0.4
RN01	2018-08-23 07:04:41	4.7	0.2
RN01	2018-08-23 14:47:17	5.2	0.9
RN01	2018-08-23 14:47:17	5.3	0.9
RN01	2018-08-23 14:57:13	4.5	0.1
RN01	2018-08-23 14:57:46	5.1	0.0
RN01	2018-08-23 15:10:54	5.3	0.4
RN01	2018-08-23 16:46:15	5.2	-0.2
RN01	2018-08-23 16:58:28	5.2	0.2
RN01	2018-08-24 01:49:31	5.3	0.2
RN01	2018-08-25 11:32:26	5.5	0.2
RN01	2018-08-25 19:01:56	4.5	0.2
RN01	2018-08-25 23:44:42	2.1	-0.2
RN01	2018-08-26 20:14:07	4.9	0.3
RN01	2018-08-26 22:59:26	5.9	0.8
RN01	2018-08-27 23:45:58	2.0	-0.2
RN01	2018-08-28 22:11:41	2.2	0.4
RN01	2018-08-29 09:49:29	2.9	0.2
RN01	2018-08-30 02:58:11	4.9	0.4
RN01	2018-09-03 20:04:17	10.6	1.0
RN01	2018-09-05 05:10:53	4.3	0.5
RN01	2018-09-05 07:13:01	6.3	0.3
RN01	2018-09-07 04:21:09	4.9	0.7
RN01	2018-09-13 13:18:11	5.0	0.9
RN01	2018-09-16 09:27:45	1.4	-0.4
RN01	2018-09-17 20:45:39	5.0	0.2
RN01	2018-09-18 00:19:25	4.5	0.1
RN01	2018-09-18 01:53:52	5.4	0.1
RN01	2018-09-18 02:03:10	4.7	0.0
RN01	2018-09-18 02:09:03	4.8	-0.2
RN01	2018-09-18 05:17:20	2.6	-0.4
RN01	2018-09-21 06:21:48	1.5	-0.6
RN01	2018-09-21 06:26:26	6.0	-0.4
RN01	2018-09-25 04:06:06	2.0	0.1
RN01	2018-09-26 11:40:49	3.7	0.2
RN01	2018-09-26 21:20:46	1.9	-0.6
RN01	2018-09-30 19:30:02	5.0	0.1
RN02	2018-07-04 05:50:12	9.3	0.1
RN02	2018-07-07 04:58:23	8.6	0.5
RN02	2018-07-10 04:54:02	8.5	0.5
RN02	2018-07-10 04:57:02	8.6	0.3
RN02	2018-07-10 05:00:19	8.7	0.4
RN02	2018-07-11 05:08:38	6.5	0.8
RN02	2018-07-11 05:37:10	7.5	0.2
RN02	2018-07-11 05:41:39	8.5	0.1
RN02	2018-07-24 02:13:30	11.8	0.6
RN02	2018-08-16 00:32:57	7.4	0.3
RN02	2018-09-18 06:30:57	7.8	0.0
RN02	2018-09-18 06:31:46	8.5	0.4
RN02	2018-09-18 06:32:38	9.7	0.1
RN02	2018-09-29 23:13:37	7.6	0.7
RN02	2018-09-30 06:29:57	8.5	0.1
RN02	2018-09-30 06:30:13	8.6	0.2
SG02	2018-07-10 09:09:07	3.1	-0.6
SG02	2018-08-28 09:20:26	5.3	0.1
SG02	2018-08-28 09:23:21	5.1	0.2
SG02	2018-09-06 14:57:26	8.0	0.4