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Decreasing yields of flowing wells in the vicinity of Newcastle, Weston County, Wyo.

By

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Contents

Illustrations

Tables

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Introduction

The U.S. Geological Survey has been making ground-water investigations in Wyoming in cooperation with the Wyoming State Engineer since 1940. These investigations have included regional studies to advance the general knowledge of the State's ground-water resources and local investigations to solve more immediate ground-water problems. As part of this cooperative program, at the request of Mr. Earl Lloyd, Wyoming State Engineer, the writer visited the Newcastle area, Weston County, Wyo., at intervals during the spring and summer of 1962, to investigate ground-water conditions in general and to collect hydrologic data on wells drilled in the Minnelusa Formation and Pahasapa Limestone in particular.

Nature of the problem

It has been known for some time that the flows of several water wells in the vicinity of Newcastle and the nearby Osage oil field have decreased, or ceased entirely, since they were drilled. A quantitative evaluation of the amount of decrease in the yield of these wells was made in the late summer of 1960, during an investigation of declining artesian pressures in water wells in the Osage oil field (Whitcomb, 1960). At the present time, most of the wells are used for domestic or stock supplies; however, two wells supply the City of Newcastle and two supply water for industries. Gradually declining artesian pressure and decreasing flows of some wells in the area have aroused concern as to the effect of additional development of ground water from the formations, principally the Minnelusa Formation and the Pahasapa Limestone, now yielding water to wells.

Method of investigation

During the initial visit to the Newcastle area in March 1962, shut-in pressures were determined for the two Newcastle wells and the well recently drilled by L. W. Carlson east of the city. Yields and shut-in pressures of the Newcastle and Sioux Oil Co. wells, when they were completed, were obtained from city and company records. An attempt was made to measure the open flow of the Carlson well, but the results were inconclusive for reasons given in a following section.

Copies of drillers' logs of the wells and details of well construction were obtained from records of the owners. Records of these wells and other wells in the area reportedly yielding water from the same aquifer, or aquifers, are given in table 1. Available drillers' logs are given in table 2.

Samples of water were collected from the Newcastle, Sioux Oil Co., and Carlson wells for chemical analysis and comparison of chemical quality. The results of these analyses and copies of earlier analyses of water from five additional wells are given in table 3.

A map of the area (fig. 1) was prepared showing areas of outcrop of

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Figure 1.--Geologic map of the Newcastle area, Wyoming, showing location of water wells drilled in the Minnelusa Formation and the Pahasapa Limestone.

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the principal geologic formations and locations of wells contained in the table of well records.

Climatological records of weather stations at Newcastle and Sundance for the period 1947-61 were studied to evaluate the effect of subnormal precipitation on recharge to the water-bearing formations in the Newcastle area. Annual and average annual precipitation for the period 1947-61 and average annual precipitation for the period 1931-52 at these stations are given in table 4.

Subsequent visits were made to the Newcastle area in May, July, and September 1962 to measure the discharge of wells in which flows reportedly had decreased and to measure the water level in one well that had ceased to flow. These measurements were recorded for comparison with reported original flows and with discharges measured by the author in August 1960. They will be essential also to the evaluation of continued declines, if any, of artesian pressures in the Newcastle area.

Data resulting from investigation

Principal aquifers

Pahasapa Limestone

The Pahasapa Limestone of Early Mississippian age, as seen in areas of outcrop, is a gray massive limestone that is about 700 feet thick in the Newcastle area (Darton, 1904, p. 3). Exposures are characteristically cavernous in their upper part, and well drillers have noted the cavernous nature of the limestone at depth. There are broad outcrops of the Pahasapa on the flanks and crest of the Black Hills north and east of the report area. The steep southwesterly dip of strata along the flanks of the Black Hills causes the formation to lie at depths ranging from about 1,150 feet in the LAK Ranch well to about 3,000 feet in the Sioux Oil Co. well (wells 5 and 3, fig. 1).

Wells drilled in the Pahasapa in the Newcastle-Osage area normally flow, and yields range from 3 gpm (gallons per minute) for the LAK Ranch well to a reported 1,450 gpm for the Newcastle well No. 1. The water contains a relatively low concentration of dissolved solids, is of the calcium bicarbonate type, and is very hard. Mineralization tends to increase, however, with distance from the area of recharge. (See table 3.)

The City of Newcastle well No. 1 (well 1) penetrates only the uppermost 26 feet of the Pahasapa Limestone. Apparently, the water-bearing zone is cavernous or fractured, although it is not so indicated in the driller's log, because when the well was completed in 1949 the flow was reported to be 1,600 gpm. The shut-in pressure was 200 psi (pounds per square inch).

The reported results of a discharge measurement made in July 1960 indicated a yield of 1,450 gpm, but the measurement was made by the trajectory method, which may be subject to considerable error. The shut-in pressure of the well in March 1962 was 180 psi.

The Newcastle well No. 2 (well 2) penetrated about 230 feet of Pahasapa before drilling was terminated. There is no record of the initial flow in 1950, but it was considerably less than that of well No. 1. The yield in July 1960 (measured by the trajectory method) was 650 gpm, and the artesian pressure was about 130 psi.

The well drilled by the Sioux Oil Co. (well 3) in 1960 yielded 117 gpm from the upper 95 feet of the Pahasapa. The shut-in pressure was reported to be 150 psi. Prior to the author's visit in March 1962, a pump had been installed in the well to obtain the additional water needed; consequently, the flow and pressure at that time could not be measured.

The principal source of water in the Carlson well (well 4) is a fractured or cavernous zone in the upper 43 feet of Pahasapa Limestone. The driller's log (table 2) first notes water at a depth of 2,717 feet, in the Pahasapa, but the overlying Minnelusa Formation undoubtedly yields some water to the well in the uncased section. In March 1962 the flow of the well was partially shut in by a control valve at the well head. This partial flow, measured with a vaned flow meter, was 475 gpm. The discharge was carried through about 1,000 feet of 4-inch irrigation pipe to the crest of a low ridge from where it flowed by gravity down the slope into a dry creek bed and thence into Little Oil Creek. The well was permitted to flow as a means of promoting its development, because when the well was opened after being shut in for a time it discharged considerable quantities of mud and sand and some large shale fragments.

After the flow in the 4-inch line had been measured, the well was shut in until the static pressure of 119 psi was reached. The 8-inch valve at the well head was then opened, and the well was permitted to flow until the discharge of mud, sand, and rocks had diminished to the point where it appeared safe to use the flow meter. Several measurements were made of the open flow, but all probably are subject to some error. The meter was operated with difficulty because of the great pressure of the water, the tendency of the discharge to surge, and the confinement of the operating space. Also, rock fragments struck the meter vanes occasionally, impeding the rate of revolution. Consequently, the calculated average discharge of 1,150 gpm may be somewhat low. The owner estimated that the well discharged nearly 1,000 gpm through a 3-inch overhead pipe used for loading tank trucks.

The well at the LAK Ranch (well 5) produces water from a zone that lies 75 to 100 feet below the top of the Pahasapa Limestone (Williams, 1948, p. 13). The lower 107 feet of the Minnelusa Formation probably yields some water to the well, but apparently the principal source is the Pahasapa. The flow of the well was reported to be about 20 gpm in 1947, but the flow measured by the author in September 1960 was 3 gpm.

The deep well at the Cambria Coal Mine (well 8), which penetrated nearly 400 feet of Pahasapa Limestone, was reported to yield about 200 gpm when completed. Darton (1904, p. 8) also stated that the Minnelusa section penetrated was so firmly cemented that it yielded no water to the well. It was not recorded whether the discharge was from artesian flow or by pumping. In September 1960, when the author visited the well, the water level stood about 37 feet below the top of the casing.

A well drilled in 1941 at the Black Hills Power and Light Plant at Osage, about 10 miles west of the report area, yields a large flow of water from a cavernous zone about 50 feet below the top of the Pahasapa (Williams, 1948, p. 14). The flow of this well has been decreasing gradually from the 800 gpm it yielded when completed in 1941. The discharge measured in 1946 was 720 gpm, and that measured in August 1960 was reported to be 580 gpm. The flow of the well is uncontrolled, and water not used by the power plant flows to waste.

Minnelusa Formation

The Minnelusa Formation of Permian and Pennsylvanian age, which overlies the Pahasapa Limestone, consists of light- to pinkish-gray fine-grained sandstone containing numerous thin beds of limestone and dolomite and some shale, gypsum, and anhydrite. The average thickness of Minnelusa logged in wells drilled in the Newcastle area is about 850 feet, although Darton (1904, p. 3) measured only about 600 feet in exposures east of Stockade Beaver Creek. Apparently, the formation thickens westward from the outcrop; however, the increase in thickness probably is exaggerated somewhat by the dip of beds along the western flank of the Black Hills. The Minnelusa is exposed over a wide area in the Black Hills lying north of the report area, but is reduced to a relatively narrow outcrop east of Newcastle. The depth to the formation at Newcastle ranges from about 1,600 feet in the Newcastle well No. 1 to about 2,100 feet in the Sioux Oil Co. well. Owing to the regional dip of beds, depths become increasingly shallow eastward, and the Minnelusa was penetrated at a depth of 252 feet in the LAK Ranch well.

Wells drilled in the Minnelusa Formation on the lower flanks of the Black Hills generally flow. Chemical analyses indicate that water from the upper part of the formation contains a relatively high concentration of dissolved solids, principally calcium sulfate and bicarbonate, and is excessively hard. It is unfit for most uses except stock watering. There is some indication, however, that water from the lower part of the formation is of much better quality. (See analysis for well 6, table 3.)

The Carlson well was so constructed that in addition to obtaining water from the Pahasapa Limestone it also yields water from the Minnelusa and overlying formations from a depth of 210 feet to about 1,950 feet through the annular space between the 7-inch casing, set in the lower part of the Minnelusa, and the 10-inch surface casing. (See log of well 4, table 3.) The Minnelusa section yields a reported flow of about 300 gpm, but the artesian head is not known. The flow is controlled, and in 1962 the water was being used in a creosoting process. The water is somewhat more highly mineralized than that obtained from other Minnelusa wells in the area, probably because it is contaminated by highly mineralized water that commonly is found in the Spearfish Formation, which overlies the Minnekahta Limestone.

The LAK Ranch well is similar in construction to the Carlson well in that it yields water from the Pahasapa through a 6-inch casing and water solely from the Minnelusa through the annular space between the 6-inch casing and 305 feet of 10-inch surface casing. The water is derived from nearly the entire thickness of the Minnelusa--about 700 feet of a total logged thickness of 900 feet. The Minnelusa section of the well produced about 50 gpm in 1947, but the flow was 41 gpm when measured by the author in September 1960. The present yield is not known. Because of poor chemical quality, the water is unsuitable for domestic use, and is marginal for stock consumption. The discharge is uncontrolled, and the water flows to waste.

The Martens Ranch well No. 1 (well 6) reportedly penetrated about 80 feet of the Pahasapa(?) Limestone. The lithologic description of the water-bearing zone, however, suggests that it is a sandstone in the lower part of the Minnelusa. (See driller's log, table 2.) The beds in this area dip steeply westward and are nearly vertical a short distance east of the well site. Although the thickness of Minnelusa strata penetrated by the well before reaching the Pahasapa(?) Limestone is comparable to the average thickness shown in logs of other wells in the area, it is probable that the thickness of the Minnelusa at the site of well 6 is exaggerated appreciably because of the steep dip of beds, and the well did not fully penetrate the formation. The flow of the well in 1948 was estimated to be about 150 gpm; the measured flow in August 1960 was only about 8 gpm. On May 30, 1962 the water level was 8.60 feet below land surface, but had risen to 7.41 feet when measured again on Sept. 28, 1962.

The chemical quality of the water indicates either that water from the lower part of the Minnelusa is very similar to that in the Pahasapa or that water in the Pahasapa, which is under greater artesian pressure, is moving upward into the Minnelusa through fracture zones.

Martens well No. 2 (well 7) reportedly yields water from the upper part of the Minnelusa Formation. The flow of the well has decreased from 20 gpm in 1948 to 8.5 gpm, measured in 1960. A chemical analysis of the water shows that it contains a relatively high concentration of dissolved solids and is of the calcium sulfate type, indicating the water is coming from a zone that contains numerous beds of gypsum.

Conclusions

As a result of the ground-water investigation in the vicinity of Newcastle, Wyo., it is concluded that the flow of many, if not all, of the water wells drilled in the Minnelusa Formation and the Pahasapa Limestone has decreased since the wells were drilled. In one well, flow has ceased completely.

The diminished flows may be due to several factors:

1. The rate of discharge from the aquifers exceeds the rate of recharge. This condition may be the result of the continually increasing withdrawal of water from the aquifers, of a decrease in recharge following several years of subnormal precipitation, or a combination of these two factors. Records of annual precipitation at Newcastle and Sundance, Wyo., for the period 1947-61 (table 4) show that precipitation during the past 15 years has been 26 to 30 percent below the normal for the 22-year period 1931-52 at these weather stations.

2. Highly corrosive waters commonly occur in the Spearfish and Minnelusa Formations, which overlie the Pahasapa Limestone. The chemical action of this water on the steel well casing may have corroded the metal to the point where sections of casing may be riddled with perforations or entirely disintegrated. Water from the Pahasapa, thus, may be permitted to escape into these overlying formations in which artesian pressures normally are less.

3. Caving of the wall rock into the well in the uncased part of the hole or as a result of casing failure may have sealed off some of the water-bearing zones in the aquifer.

4. Water in both the Minnelusa Formation and the Pahasapa Limestone contains calcium bicarbonate in solution under great pressure. The decrease in pressure upon the water in the aquifer in the vicinity of a flowing well may cause calcium carbonate, if in sufficient concentration, to precipitate from solution and to be deposited in the interstices of the adjacent wallrock and openings of well screens and perforated casings. Eventually, chemical incrustation may attain sufficient extent and thickness to appreciably impede the entrance of water into the well.

Because all the conditions enumerated above may be contributing to the observed gradual decline of water levels in and decrease in discharge from some wells in the Newcastle area, it would be impossible to determine the principal cause without a continuous, and probably prolonged, study of ground-water conditions in the area and in other areas where similar hydrologic and climatologic conditions are in effect. Measurements of water levels and discharges from wells yielding water from the Minnelusa Formation in the valley of Belle Fourche River, between Devils Tower and Hulett, indicate that artesian heads are lower and flows have decreased since the wells were drilled. The total withdrawal from the Minnelusa in this area is small, and the wells are believed to be too widely spaced for withdrawals to cause mutual interference.

Future drilling in the Newcastle area should be governed by the principle that changes in ground-water storage in an artesian aquifer may be accompanied by changes in artesian pressure that normally are effective over a wide area. Artesian pressures will decline when the rate of withdrawal from the aquifer exceeds the rate of recharge, and will recover when the reverse condition is in effect until a state of equilibrium is reached. Wells drilled too closely together in the same aquifer may mutually interfere and cause a local decline in artesian pressure and decrease in yield of both wells.

Continuing studies in the Newcastle area

The results of the investigation indicate that the flows of some of the wells in the Newcastle area have decreased since they were drilled. It would be desirable to know if the declines in yield and artesian pressure are continuing and, if so, at what rate. Where possible, discharge and pressure measurements should be made periodically and recorded for future comparison. It would be beneficial to control the flows of wells now in use so that as little water as possible is wasted, and to plug any wells that are of no economic value. Measurements of water levels, artesian pressures, and discharges of wells tapping the Minnelusa and Pahasapa Formations in adjacent areas also should be made periodically to determine if there is a wide-spread trend in artesian pressures in these formations and to compare conditions with those in the Newcastle area.

References cited

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Whitcomb, H. A., 1960, Investigation of declining artesian pressures in the vicinity of Osage, Weston County, Wyo.: U.S. Geol. Survey open-file report, 11 p., 1 fig.

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63-139

Table 1.--Record of wells yielding water from the Minnelusa Formation and the Pahasapa Limestone in the vicinity of Newcastle, Wyo.

Discharge: N, not flowing; R, reported measurement.

Method of lift: F, flows; N, none; P, pumped.

Use of water: D, domestic; I, industrial; Ir, irrigation; N, none; P, public; S, stock.

Water level: R, reported measurement.

No. on map (fig. 1)	Location	Owner	Year drilled	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Principal geologic source	Discharge (gpm)	Method of lift	Use of water	Water level above (+) or below land surface (feet)[a]	Altitude of land surface (feet)	Date of measurement	Remarks
1	SW¼SE¼ sec.20,T.45 N.,R.61 W.	City of Newcastle	1949	2,638	7	2,618	Pahasapa Limestone	1,600± R 1,450± R	F F F	P P P	+460 R ..... +415	4,360 4,360 4,360	1949 7/--/60 3/15/62	Method of measuring discharge subject to error
2	SE¼NE¼ sec.30,T.45 N.,R.61 W.	.....do.....	1950	3,028	7	2,800	.....do.....	650± R	F	P	+300±	4,280	7/--/60	
3	NW¼SW¼ sec.29,T.45 N.,R.61 W.	Sioux Oil Co.	1960	3,073	.....	2,978	.....do.....	117 R	F	I	+345 R	4,240	5/--/60	Pump installed to increase yield
4	NW¼NE¼ sec.28,T.45 N.,R.61 W.	L. W. Carlson	1961	2,738	7	2,468	.....do.....	1,150+	F F	S S	+275 +270	4,440 4,440	3/16/62 5/30/62	Discharge measurement questionable. Well had been shut in 2 weeks
				1,950	10	210	Minnelusa Formation	300 R	F	I	.....	4,715	9/--/61	Water flows between 7- and 10-inch casing of deep well. Flow controlled
b 5	NW¼NW¼ sec.5,T.44 N.,R. 60 W.	LAK Ranch	1945	1,300	6	1,045	Pahasapa Limestone	20 R 3	F F	D D	....	4,440 4,440	1947 9/ 1/60	Flow uncontrolled 9/1/60
				1,010	10	305	Minnelusa Formation	50 R 41	F F	S S	....	4,440 4,440	1947 9/ 1/60	Water flows between 6- and 10-inch casing of deep well, uncontrolled.
b 6	NE¼NW¼ sec.31,T.46 N.,R.60 W.	F. Martens	1941	1,178	.....	1,100	Lower part of Minnelusa(?) Formation	150 R 8 N	F F P	Ir Ir Ir	.... 7.41	4,760 4,760 4,760	1948 9/ 1/60 9/28/62	No control of flow
b 7	SW¼NW¼ sec.2,T.45 N.,R.61 W.	.....do.....	1933	720	6	619	Upper part of Minnelusa Formation	20 R 8.5	F F	S S	....	4,700 4,700	1947 9/28/62	
b 8	NE¼NW¼ sec.29,T.46 N.,R.61 W.	Cambria Coal Mine	1900±	2,345	8	.....	Pahasapa Limestone	N	N	N	36.98	5,100±	9/ 1/60	Well reported to yield 200 gpm when completed
b (c)	SW¼SE¼ sec.10,T.46 N.,R.63 W.	Black Hills Power & Light Co.	1941	2,592	10-6	2,485	.....do.....	800 R 720 R 580 R	F F F	I I I	+405 R	4,350± 4,350± 4,350±	1941 1946 1960	Discharge before casing installed reported to be 2,200 gpm. No control of flow

[a] Water levels above land surface datum measured as pressure (psi) and converted to feet by using conversion factor 2.31 x psi.

[b] Data obtained prior to 1960 abstracted from Williams (1948).

[c] Well at Osage, about 10 miles west of mapped area.

Table 2.--Drillers' logs of wells shown on figure 1.

Well 1 (Newcastle well No.1)

Alluvium	170	170
Fall River and Lakota Formations	255	425
Morrison Formation	125	550
Sundance Formation	465	1,015
Spearfish Formation	500	1,515
Minnekahta Limestone	70	1,585
Opeche Formation	45	1,630
Minnelusa Formation	982	2,612
Pahasapa Limestone	26	2,638

Well is cased to 2,618 feet

Well 2 (Newcastle well No.2)

	Thickness (feet)	Depth (feet)
Belle Fourche and Mowry Shales	523	523
Newcastle(?) Sandstone	144	667
Limestone(?) and sandstone	78	745
Fall River(?) and Lakota(?) Formation	305	1,050
Morrison(?) and Sundance(?) Formations	325	1,375
Spearfish Formation:		
Red beds	525	1,900±
Minnekahta Limestone and Opeche Shale	130	2,030
Minnelusa Formation	780	2,810
Pahasapa Limestone	218	3,028

Well is cased to 2,800± feet

Table 2.--Drillers' logs of wells shown on figure 1.--continued

Well 3 (Sioux Oil Co.)

	Thickness (feet)	Depth (feet)
Belle Fourche and Mowry Shales	350	350
Newcastle Sandstone	150	500
Skull Creek Shale	110	610
Fall River Formation	190	800
Lakota Formation	135	935
Morrison Formation	285	1,220
Sundance Formation	220	1,440
Gypsum Spring Formation	60	1,500
Spearfish Formation	500	2,000
Minnekahta Limestone and Opeche Shale	130	2,130
Minnelusa Formation	835	2,965
Pahasapa Limestone	108	3,073

Well is cased to 2,978 feet

Well 4 (Carlson)

	Thickness (feet)	Depth (feet)
Skull Creek Shale	150	150
Fall River and Lakota Formations	185	335
Morrison and Sundance Formations	682	1,017
Spearfish Formation	786	1,803
Minnekahta Limestone and Opeche Shale	104	1,907
Minnelusa Formation	788	2,695
Pahasapa Limestone	43	2,738

Well is cased to 2,468 feet

Table 2.--Drillers' logs of wells shown on figure 1.--continued

Well 5 (LAK Ranch)

Alluvium	25	25
Spearfish Formation	80	105
Minnekahta Limestone	60	165
Opeche Formation	87	252
Minnelusa Formation	900	1,152
Pahasapa Limestone	148	1,300

Well is cased to 1,045 feet

Well 6 (Martens well No. 1)

	Thickness (feet)	Depth (feet)
Alluvium	55	55
Spearfish Formation	108	163
Minnekahta Limestone and Opeche Shale	98	261
Minnelusa Formation:		
Sandstone and shale	499	760
Shale	30	790
Sandstone, hard	134	924
Sandstone and shale	56	980
Sandstone, hard	117	1,097
Pahasapa(?) Limestone:		
Limestone	8	1,105
Sandstone	73	1,178

Well is cased to 1,100± feet

Table 2.--Drillers' logs of wells shown on figure 1.--continued

Well 7 (Martens well No. 2)

Alluvium	60	60
Sundance Formation	10	70
Spearfish Formation	470	540
Minnekahta Limestone	45	585
Opeche Shale	37	622
Minnelusa Formation	98	720

Well is cased to 619 feet

Well 8 (Cambria Coal Mine)

	Thickness (feet)	Depth (feet)
Alluvium:		
Sand and Gravel	20	20
Morrison Formation	130	150
Sundance Formation	346	496
Gypsum Spring Formation	8	504
Spearfish Formation	484	988
Minnekahta Limestone	34	1,022
Opeche Shale	74	1,096
Minnelusa Formation	851	1,947
Pahasapa Limestone	398	2,345

No casing record

Table 3.--Chemical analyses of water from the Minnelusa Formation and the Pahasapa limestone in the vicinity of Newcastle, Wyo.

[Results in parts per million. Analyses by U.S. Geological Survey, except where indicated otherwise.]

No. on map (fig 1)	Owner	Date of collection	Principal geologic source	Depth (feet)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue on evaporation 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	pH
[a]1	City of Newcastle	1/ 7/50	Pahasapa Limestone	2,638	.....	9.0	....	54	33	6.9	.....	34	5.0	....	.....	.....	290	335	.....	....
1	.....do.....	3/16/62	.....do.....	2,638	79	13	0.03	63	28	4.1	291	38	1.2	0.3	0.9	0.03	291	274	35	7.7
[b]2	.....do.....	1/26/54	.....do.....	3,028	.....	.....	....	.....	.....	5.4	.....	.....	.....	.4	.....	.....	440	332	.....	7.6
2	.....do.....	3/16/62	.....do.....	3,028	86	14	.04	76	32	7.2	268	105	1.8	.4	.9	.01	386	322	102	7.4
3	Sioux Oil Co.	....do....	.....do.....	3,073	81	14	.06	76	33	8.7	257	117	2.5	.4	1.0	.02	405	327	116	7.4
4	L. W. Carlson	3/16/62	.....do.....	2,738	79	13	.07	62	29	4.7	269	37	1.4	.3	.9	.01	288	273	36	7.4
4	.....do.....	....do....	Minnelusa Formation	1,950	74	10	.62	604	161	36	127	1,980	19	.9	2.1	.15	3,220	2,170	2,070	7.4
5	LAK Ranch	12/10/47	Pahasapa Limestone	1,300	58	7.6	0	55	13	45	300	27	2.8	.7	1.8	0.14	298	191	0	7.2
5	.....do.....	....do....	Minnelusa Formation	1,010	57	5.0	.05	474	84	37	225	1,310	11	1.8	2.2	.....	2,020	1,530	1,350	7.2
6	F. Hartens	....do....	Lower part of Minnelusa(?) Formation	1,178	60	11	.05	58	9.8	43	306	16	1.8	.5	1.5	.1	290	185	0	7.1
7	.....do.....	....do....	Upper part of Minnelusa Formation	720	58	6.0	.05	504	142	37	136	1,720	3.8	2.4	1.8	.....	2,400	1,840	1,730	7.5
[c]	Black Hills Power & Light Co.	....do....	Pahasapa Limestone	2,592	76	5.6	.05	70	19	20	296	47	1.2	.6	1.0	.07	366	252	9	7.1

[a] Analysis by South Dakota School of Mines.

[b] Analysis by Wyoming Department of Public Health.

[c] Well at Osage, about 10 miles west of mapped area.

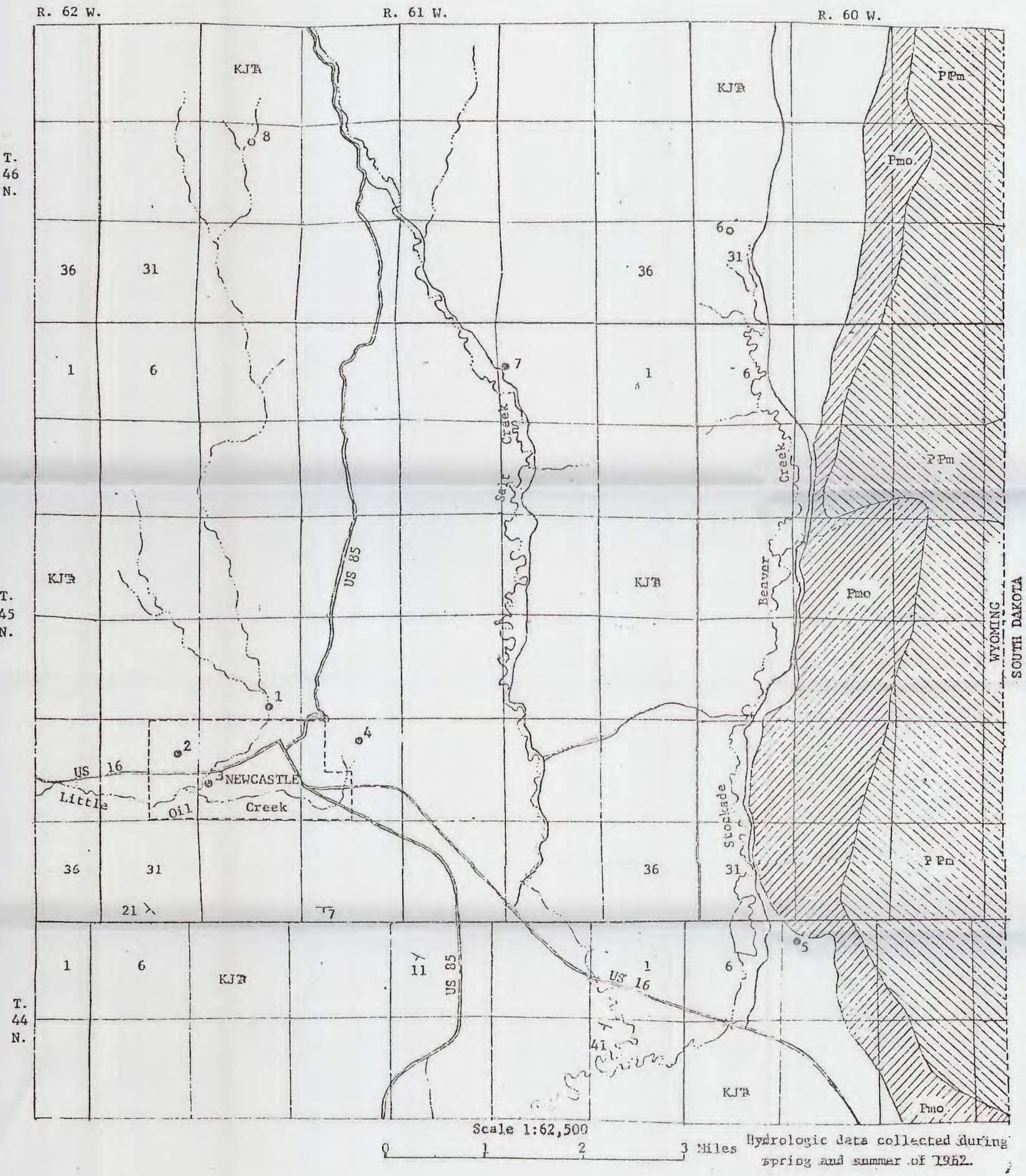
Table 4.--Precipitation, in inches of water, at Newcastle and Sundance, Wyo., 1947-61.

[From records of the U.S. Weather Bureau.]

Year	Newcastle	Sundance
1947	14.74	14.67
48	10.70	11.99
49	10.93 E	14.81
50	9.59 E	13.20
51	10.59 E	17.96
52	10.64	12.95
53	14.97	15.83
54	11.21	11.58
55	16.08	20.37
56	11.49	12.11
57	16.24	16.67
58	14.47	15.45
59	12.10	13.29
60	7.76	-----
61	7.09	13.16
Average	11.91	14.55
Average for period 1931-52	16.09	20.76
Percent below normal	26	30

E, estimated. Record incomplete.

63-139



Hydrologic data collected during spring and summer of 1962.

Explanation

KJT

Shale and siltstone.

Some sandstone in middle part and beds of gypsum in lower part

TRIASSIC, JURASSIC, AND CRETACEOUS

Pmo

Minnekahta Limestone and Opeche Shale

Gray limestone and purple and maroon shale

PPm

Minnelusa Formation

Light- to pinkish-gray sandstone containing variable amounts of limestone, dolomite, anhydrite, gypsum, and shale

PERMIAN

PENNSYLVANIAN AND PERMIAN

21

Strike and dip of beds

o 2

Flowing well

Number identifies well

o 8

Non-flowing artesion well

Wells shown on map

1. Newcastle No. 1
2. Newcastle No. 2
3. Sioux Oil Co.
4. Carlson
5. LAK Ranch
6. Martens No. 1
7. Martens No. 2
8. Cambria Coal Mine

Figure 1.--Geologic map of the Newcastle area, Wyoming, showing location of water wells drilled in the Minnelusa Formation and the Pahasapa Limestone.