THE GEOLOGICAL SURVEY OF WYOMING

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S. H. Knight, State Geologist
University of Wyoming
Laramie, Wyoming

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PURPOSE

The field and laboratory work on which this report is based was carried out with the view of (1) recommending means of providing temporary increases in the flow of water obtained from the present source in order to take care of periods of high consumption, such as the lawn irrigation season, (2) providing data for recommendations for future engineering developments designed to increase, during periods of low municipal consumption, the amount of water stored in the natural underground reservoir, and (3) ascertaining whether or not the present source of municipal water supply is likely to be adequate for the future needs of the city with the most conservative use.

FIELD WORK

The period of field investigation extended from April 1 to May 15, 1937. Those who participated were S.H. Knight, State Geologist of Wyoming, R.H. Beckwith, Associate Professor of Geology, University of Wyoming, A.M. Morgan, Assistant, Geological Survey of Wyoming, up to April 10, 1937, and various undergraduate and graduate students in the Department of Geology, University of Wyoming. Student work was performed under the active supervision of the writer and was checked in the field by him. Field and laboratory work consisted of (1) areal geological mapping with plane table and telescopic alidade, on a scale of 1 inch = 1,000 feet, of approximately six square miles, (2) determination with plane table of the elevations of certain critical points, (3) reconnaissance mapping of the Forelle limestone, (4) the assembling of stratigraphic sections of the Casper and Satanka formations, (5) field and laboratory examination of recently drilled wells in the vicinity of the springs, and the logs and cuttings from these wells, and (6) examination of the springs from which the water supply is drawn. The total time used on the field work was 30-man days.

LOCATION, TOPOGRAPHY AND DRAINAGE

Laramie draws its water supply from three artesian springs, (Pl. 1) City Springs in sec. 35, T. 16 N., R. 73 W., Pope Springs in sec. 14, T. 15 N., R. 73 W., and Soldier Springs in sec. 23 of the same township.

The top of the Laramie range is a gently rolling surface above which project a few bold mountains. The top of the range is drained by eastward-flowing streams, which head along a north-south line approximately five miles east of the line of springs. These streams constitute a part of the South Platte drainage. The west side of the Laramie Range is a belt about five miles wide, bounded on the east by the divide between the South Platte and the Laramie River drainages and on the west by the line of the artesian springs. Elevations along the divide between Summit Inn and Pilot Knob vary from approximately 8,500 to 8,900 feet. From the divide a gently rolling surface descends westward, in a horizontal distance of approximately five miles, to the spring line at elevations of approximately 7,270 to 7,350 feet.

The rolling surface is cut by a few deep, steep-sided canyons, such as Telephone Canyon, through which U.S. Highway 30 passes between Laramie and Summit Inn. There are no permanent streams in any of these canyons. Most of the precipitation which falls in the belt between the Laramie Range watershed and the spting line sinks into the ground, and, as will be shown later, is the source of the Laramie municipal water supply.

For a few days of the year there are streams in the canyon beds, but only during times of extraordinarily heavy rains or during rapid melting of the snow. On April 10, 1937, a warm day soon after a snow storm, a stream of probably 3 to 4 cubic feet per second was flowing in one of the canyons two miles east-northeast of Soldier Springs. There was, however, a noticeable diminution in volume near the west base of the range, and all of the water sank into the ground within a distance of a few hundred feet west of the spring line.

A belt extending two to five miles west of the spring line to Fivemile Creek and the Laramie River is almost flat. The only streams in this area are Spring Creek and Soldier Creek, which receive their water from the springs.

STRATIGRAPHY

Pre-Cambrian granites.- The oldest rocks in the area under consideration are the pre-Cambrian granites. They are coarse-grained, pink, non-stratified rocks consisting of quartz, pink feldspar and a little black mica. They are exposed at the surface east of the Laramie Range divide, extend westward beneath the younger sediments and have been encountered in deep borings in Laramie. The granites have a very low porosity and are not water-bearing. Since they lie beneath all the other rocks, the depth to which water can move downward is limited by the depth to the granites.

Casper formation.- Lying on the eroded surface of the granites is a succession of alternating beds of porous sandstone and compact, thick-bedded limestone with a total thickness of approximately 700 feet.

The limestones are not more than a few feet thick and are not continuous. Several of them in the area mapped in detail thin and pinch out laterally. The limestones have little or no porosity and consequently are not water-bearing. They serve effectively to stop movement of water across bedding, except in places where the beds are fractured, such as is the case at the artesian springs, or where penetrated by a boring.

The sandstones are yellowish, white, orange and pink in color. A feature which is common in most places is a marked cross-bedding. Some of the beds are more than 50 feet thick. The grains of the sandstones are almost perfect spheres with little size variations and in most places the grains are not well cemented together. These conditions make for a high porosity. The artesian water from the three springs comes from the sandstones of the Casper formation. Some of the wells in Laramie and vicinity also draw from them.

Satanka formation.- The Satanka, which lies conformably on the Casper, consists almost entirely of bright red shales and sandy shales. There is apparently some variation in total thickness between the limits of 200 and 250 feet in the area under consideration. The shales and sandy shales, although saturated with water everywhere beneath the water table, are so fine-grained that they do not release water and therefore cannot be considered as water-transmitting beds or aquifers. Since the shales and sandy shales lie on top of the upper sandstone of the Casper, they are effective cap rocks which prevent water from moving upward except in wells.

In sec. 35, T. 15 N., R. 73 W., east of the railroad track, there is a sandy zone in the Satanka. The sandy zone is 15 feet thick and occurs approximately 100 feet above the top sandstone of the Casper labeled on the map (Pl. 1) as the Top sandstone. The sandy zone extends at least as far northward as Pope Springs. There are two poor exposures of the sandstone north and south of Soldier Creek between the springs and the railroad track.

Forelle formation.- The Forelle, which lies conformably on the Satanka, consists of a lower gray to purple crinkled ribbon limestone, a middle red shale, and an upper gray to purple crinkled ribbon limestone. The total thickness of the Forelle is approximately 20 feet. The limestones are locally slightly porous and pumping wells of small flow can be obtained by penetrating the Forelle close to the surface.

Chugwater formation.- The Chugwater, which lies conformably on the Forelle, consists of approximately 1,000 feet of red shale with a few thin gypsum beds near the base. Locally there are a few thin red sandstones from which water can be obtained, but not in sufficient quantity to be of importance in municipal water supply.

Detailed stratigraphic sections.- In the time available for the mapping, it was not possible to cover an area extending more than a mile and a half east of the spring line. Since the lower beds of the Casper crop out near the crest of the Laramie Range, the detailed section given below includes only the upper beds of the Casper. The log of the Monolith well indicates, however, that these are the major water-bearing beds and cap rocks. The section below was assembled from plane-table locations and elevations taken east of Pope Springs, along Pope Draw west of the springs, and on the Foreèle ridge north of Pope Draw.

	Thickness in feet		Thickness in feet
Pope Springs section		Monolith Well log	
Forelle limestone		Forelle limestone	
Red shale and sandy shale	220	Red sandy shale	104
		Red sandy shale, caving	28
		Red sandy shale with gypsum streaks	5
		Red sandy shale	100
Pope Springs sandstone	3	Red sandy shale, little water	5
Red sandstones and sandy shales	65	Red sandy shale	82
Limestone 2	2	Lime	5
Sandstone 2	40	Red shale	27
Limestone 3	5	Lime	11
Sandstone 3	13	Soft coarse gray sand, water, large flow	58
Limestone 4	0-5		
Sandstone 4			

In details of thickness of beds and description of the character of the sediments of individual beds there are numerous discrepancies. They are the result of the almost complete lack of exposures of the Satanka along the line of section used by the writer and the difficulty of telling from drill cuttings the exact nature of the beds being penetrated without microscopic examination of the cuttings. In addition, in the mapping it was noted that there is considerable variation in character of sandy and shaly beds. Limestone 4 does not appear in the Monolith log. This is easily explained, since it is known from the detailed mapping that Limestone 4 is absent in the ridge north of the lower end of Cheyenne Canyon, but is present both to the north and south.

On the whole there is satisfactory correlation between the two sections. The Pope Springs sandstone, Limestone 2, and Limestone 3 fall very closely at the same stratigraphic horizons in both sections. Thicknesses from the bottom of the Forelle to the top of Limestone 3 are respectively 330 feet and 224 feet.

STRUCTURE

The artesian springs are located on the west flank of the Laramie Range anticline. For several miles both east and west of the spring line the strikes of the Casper, Satanka and Forelle vary little from N. 20° E., except locally in the immediate vicinity of City Springs and Soldier Springs. The beds dip westward at $2\frac{1}{2}°$ to 5°, except locally on folds described below. To the south the outcrop of the Casper swings around the south end of the Laramie Basin syncline, but at a higher elevation than the springs. On the west side of the Laramie Basin syncline the Casper crops out in a few places, at elevations higher than the springs, or is effectively sealed off beneath pre-Cambrian rocks along thrust faults. To the north the Casper crops out at the head of Laramie River Canyon at elevations somewhat lower than the springs, but at a distance of some 40 miles. Any escape of water northward is negligible.

Both Soldier and City Springs come out near the base of the Satanka formation and near the axial planes of minor anticlines, which produce marked changes in the general northward strikes of the beds. Both of the minor anticlines trend almost due west and plunge in the same direction. The Soldier Springs anticline is strongly asymmetric. Dips on the south flank are only a few degrees. On the north flank near the mouth of Cheyenne Canyon the beds dip to the northwest at angles as great as 60°.

It is not certain that Pope Springs is on an anticline. The change of trend of the top of Limestone 2 east of the springs may indicate a slight change in strike. No accurate topographic map of this area has been made, and consequently the swing may be the result of change of elevation of land surface along the top of Limestone 2 rather than the result of a change in strike around the nose of an anticline.

On the north flank of Soldier Springs anticline there are several faults. Their displacement is only a few feet. On both the north and south flanks of City Springs anticline there are faults (not shown on the map) of a few feet displacement.

CONCENTRATION OF WATER AT THE SPRINGS

This section can be conveniently read in connection with figures 1 and 2. The legend for figure 2 is the same as that for figure 1. Both of these drawings are merely qualitative. True distances and depths cannot be scaled from them. Figure 2 is a cross section drawn along the gulch in the block diagram and extends both east and west beyond the limits of the block.

No water enters the structure from the granite area east of the watershed of the Laramie Range. The lower beds of the Casper formation form a low ridge along the crest of the Laramie Range and the surface of the granites slopes eastward from here. Consequently all precipitation which falls on the non-porous granites east of the bottom of the Casper goes to form surface streams draining into the South Platte.

Precipitation which falls on the sandstones sinks into them and percolates downward and westward except in times of very heavy runoff, when streams may form and drain into the main gulches. Even most of this surface drainage is taken up from the streams where they cross sandstones in the upper part of the Casper. Precipitation falling on a limestone bed is not absorbed, but runs down its bare surface , as indicated by the arrows in the diagram, and is absorbed by the sandstone bed lying above the limestone.

The pore space of the sandstones is completely filled by the water at some distance below the surface, and water tables are established at a,b, c, i, a', b' and c'. Since d is higher than e it is probable that the water table in the lower sandstone bed at a is higher than in the upper bed at b. If there were no escape from the sandstone at elevations lower than their outcrops there would be small springs at d and e as well as at f.

In the process of folding, however, the arching effect on the crest of the anticline merely bent the shales (Satanka), which flow easily under pressure, but produced tension fractures in the more brittle limestones and sandstones of the Casper. Some of these fractures in the exposed part of the Casper have had sufficient movement to appear as faults, causing repetition or offset of beds.

The differences in elevation between the water tables at a and b, and f, the lowest point at which the fractures reach the surface, causes water from the lower sandstones to move upward through the fractures across the impervious limestones and issue forth at f as an artesian spring.

It is to be noted from the map (Pl. 1) that some of the water which comes out at the springs entered miles away and that the volume of water which can be stored in the pore space of the sandstone is very large. Consequently, although the flow of the springs is ultimately entirely dependent upon prepipitation, a decrease in precipitation might be expected to have little effect on decreasing appreciably the flow of the springs for several years and, conversely, an increase in precipitation might not be expected to increase the flow of the springs for a corresponding period of years.

GENERAL EFFECT OF DRILLING WELLS

The surface of the ground west of the spring line slopes gently downward to the west at an angle lower than the dip of the beds. Consequently to the westward the Casper aquifers are deeper beneath the surface, but the land surface is lower than the springs. A well drilled west of the spring line and penetrating the Casper sandstones, as at g, permits water to move upward across the limestones and impervious shales. If the well collar is far enough below the springs to overcome the friction of flow of water through the pore space of the sandstones, the water flows out above the ground.

Such a well obtains more water, but water which would normally come out at the springs. For somebody who is not connected with the city system this is a clear gain. Water obtained in such a way and turned into the city mains may give a temporary increase, but will have ultimately an adverse effect on the flow of the springs. Some of the wells in Laramie and vicinity draw their water from the Casper aquifers. Othere do not.

The sandy zone in the Satanka is exposed in a few places, about half way between the top of the Casper and the bottom of the Forelle, and extends northward under alluvial cover as far north as Pope Springs. This sandstone, which is approximately 15 feet thick in the southern part of the mapped area, receives some of the runoff from the main gulches heading in the Laramie Range at times when there is heavy enough runoff for water to flow west of the top of the Casper. In addition, the Satanka sandy zone receives local precipitation and overflow water from Pope and Soldier Springs. Wells drilled at elevations below that of the outcrop of the Satanka sandy zone and encountering it at depths of several hundred feet or less, as at h, have given good flows. These wells have no effect on the flow of the springs.

GENERAL EFFECT OF EXCAVATING AT SPRINGS

At both Soldier and City Springs trenches have been dug into the hillside to tap the water of the springs at an elevation a few feet lower than their natural outlets. In addition, a shaft was dug near the west end of the Soldier Springs enclosure. This shaft penetrates the lower few feet of the upper sandstone of the Casper formation and a hole more than a foot in diameter has been broken through Limestone 1 permitting water to flow out of Sandstone 1.

The effect of such development is to increase the difference in elevation between spring outlet at f and the water tables at a, b, c, i, a', b', and c'. The water in the sandstones therefore flows out of the sandstones faster. Unless there is an increase in precipitation, however, the water tables are lowered and the increased flow at the springs is obtained by drawing on reserves in the natural underground reservoirs. It is to be emphasized that <u>this procedure does not obtain any water which would not eventually come out at the springs.</u>

In order to obtain a quantitative estimate of how much water is drawn from underground reserves by lowering the outlets of all three springs to the extent of five feet the following data will serve.

Lowering of spring outlets	5 ft.
Length (N-S) of the catchment area from which the springs draw	6 mi. = 31,600 ft.
Average width (measured E-W) of outcrop of the Casper formation	5 mi.
Average total width of the water tables (measured E-W) in the various sandstones of the Casper formation	2 mi. = 10,560 ft.
Porosity of the Casper sandstones . . .	10%
1 cu. ft. = $7\frac{1}{2}$ gal.	

The volume of water withdrawn from underground reservoirs during the period between time of lowering of outlets to time of return of springs to their normal flow = $5 \times 31,600 \times 10,560 \times \frac{1}{10} \times 7\frac{1}{2} = 1,250,000,000$ gal.

On the basis of the figure of Laramie's water consumption of 4,000,000 gallons per day given by the City Engineer* the amount of water withdrawn by lowering the spring outlets 5 feet is sufficient to supply the city for 310 days.

Construction work should be carried out at both springs to provide means of lowering or raising at will the level of exit from the springs. Such work would necessarily be carried out by an engineer, but the plans and execution should be carried out with the aid of a competent geologist familiar with the details of the Laramie water supply.

NEWLY DRILLED WELLS

The information as to location, depth, and flow of the wells discussed below were obtained from Mr. E. K. Nelson, City Engineer, with the exception of the figure for the depth of the well at the Rosedale Dairy, which was given in writing to the State Geologist by the driller of the well. Conclusions given below are based on the assumption that the data provided are correct.

Howe Wells.- Location NE$\frac{1}{4}$ sec. 22, T. 15 N., R. 73 W. Drilled September, 1936. East well. Elevation 7,274 feet, depth 156 feet. Flow 200,000 gallons per day. West well, Elevation approximately the same as that of the other well. Depth 175 feet. Flow 100,000 gallons per day.

*Elmer K. Nelson. Memorandum on the development of water supply at Soldier Springs area. p. 7, February 18, 1937.

The well collars are a few feet stratigraphically above the top of the Forelle. Since the thickness of the Satanka in this locality is around 200 to 250 feet, the wells are drawing from the Satanka sandy zone and not from the Casper. Some of the water from the wells fell as precipitation on the sandy zone. Soldier Creek crosses the outcrop of the Satanka sandy zone east of the wells at a higher elevation, and consequently some of the water from the wells is overflow from Soldier Springs. The conditions at this well are represented diagrammatically by the well at h (Fig. 2).

Rosedale Well.- Location NE cor. NW ¼ sec. 15, T. 15 N., R. 73 W. Drilled April, 1937. Elevation approximately 7,250 feet. Depth 186 feet. Flow 170,000 gallons per day.

The well collar is 20 to 50 feet above the Forelle. The bottom of the well is therefore in the Satanka sandy zone, as at h (Fig. 2), and the well is not drawing from the same source as the municipal springs.

Wallis Well.- Location SW ¼ sec. 14, T. 15 N., R. 73 W. Drilled October, 1936. Elevation approximately 7,300 feet. Depth 215 feet. Flow 50,000 gallons per day. Bottom in white limestone.

The well collar is on the Satanka approximately 135 feet stratigraphically above the Pope Springs sandstone. The bottom of the well is therefore within the Casper formation, probably in Sandstone 2, as at g (Fig. 2). This well is therefore drawing water which would normally come out at Pope Springs.

The figure for flow given to the writer by the City Engineer is somewhat above the present flow. The writer gauged the well on May 15, 1937, using a gallon can. The flow was 1 gallon in 2 seconds, or approximately 40,000 gallons per day. This is equivalent to about one percent of the combined flow of the municipal springs.

POSSIBLE NEW MUNICIPAL WELLS

Near Pope Springs.- The writer was informed by the City Engineer during the second week in May, 1937, that the only place in the vicinity of Pope Springs where the city had a right to drill is in a 5-acre tract 1,100 feet west of Pope Springs. This location is stratigraphically below the sandy zone in the Satanka and any water obtained here would necessarily be obtained from the Casper. The well collar at this vicinity would be only about 10 feet lower than Pope Springs, from which there is a flow of only about 50,000 gallons per day at present. It is likely that no large flow could be obtained from such a well without pumping, if the well is drilled only to the same bed as that reached in the Wallis well. As a maximum figure for flow without pumping, the flow of the Wallis well, which is collared at least 20 feet lower, would serve. This flow of 40,000 gallons per day is about 1 percent of the combined flow of the springs. If such a well is drilled, it should go at least deep enough to reach Sandstone 4, which should be encountered at a depth of about 200 feet. Since the water tables in the lower sandstone of the Casper are higher than in the upper sandstones, it is likely that larger flows could be obtained by drilling into beds lying below the one tapped by the Wallis well.

A well drilled on the tract west of Pope Springs would eventually have an adverse effect on Soldier and City Springs. The well collar would be only about 10 feet above Soldier Springs and 60 feet above City Springs. At best, the drilling of such a well would be merely a temporary expedient to augment the municipal supply at a time of great need.

To the Satanka sandy zone.- Wells to draw from the Satanka sandy zone would have to be drilled west of the Horelle ridge in order to have outlets far enough below the outcrop of the sandy zone to give a flow. It is to be noted that these wells are located in draws down which water from the municipal springs is running at present, or has run recently, across the outcrop of the Satanka sandy zone.

It is the writer's opinion that drilling of municipal wells would be, at best, merely a temporary expedient and would give only a small percentage increase in water available for municipal supply. The combined flow from the four wells drilled within the last year is about 500,000 gallons per day, or about 12 percent of the combined flow of the municipal springs. Nine-tenths of this was obtained from the Satanka sandy zone. Obtaining water from this horizon would almost certainly involve considerable expense for drilling, acquisition of land, and possibly for new pipe line and pumping. Judging from the poor exposures available, the Satanka sandy zone is thin and has comparatively little catchment area. It is probable that the underground reserves are too small to justify the cost of tapping and using them.

INADEQUACY OF THE PRESENT WATER SUPPLY FOR FUTURE NEEDS

It has been shown (1) that the present water supply is derived from the precipitation falling on an area of approximately 30 square miles between the spring line and the crest of the Laramie Range, (2) that borings into the Casper west of the spring line merely obtain water from the same source as that from which the springs draw,

(3) that small and uncertain amounts of underground water might be obtained by drilling to the Satanka sandy zone west of the Forelle ridge, probably at considerable expense for land and possibly for additional pipe lines and pumps, and (4) that during the last few years the flow of the artesian springs has been maintained or increased by lowering the outlets, a process which merely draws on underground reserves.

Precipitation.- The amount of water which can be obtained from the Casper formation, and secondarily from the Satanka zone, is ultimately dependent upon precipitation. The table below gives the annual precipitation figures for the Laramie Station of the United States Weather Bureau*.

TABLE I

ANNUAL PRECIPITATION AT LARAMIE

46-year mean 1891-1936 = 10.88 inches

Year	Annual Precipitation in inches	5-year mean in inches	Deficiency (-) or excess (+) from 46-year mean in inches	Accumulated deficiency or excess in inches
1891	13.92			
1892	12.44			
1893	3.75	9.77	-7.13	-7.13
1894	7.63		-3.25	-10.38
1895	11.18		+.30	-10.08
1896	12.80		+1.92	-8.16
1897	12.46		+1.58	-6.58
1898	7.63	10.67	-3.25	-9.83
1899	11.85		+.97	-8.86
1900	8.58		-2.30	-11.16

*Kindly provided by Professor F.E. Hepner, University of Wyoming.

1901	8.52		-2.36	-13.52
1902	7.65		-3.23	-16.75
1903	10.37	9.18	-.51	-17.26
1904	9.58		-1.30	-18.56
1905	9.78		-1.10	-19.66
1906	12.57		+1.69	-17.97
1907	9.46		-1.42	-19.39
1908	13.54	11.14	+2.66	-16.73
1909	9.69		-1.19	-17.92
1910	10.45		-.43	-18.35
1911	9.91		-.97	-19.32
1912	14.85		+3.97	-15.35
1913	13.66	12.15	+2.78	-12.57
1914	9.92		-.96	-13.53
1915	12.36		+1.48	-12.05
1916	10.18		-.70	-12.75
1917	9.98		-.90	-13.65
1918	12.84	11.42	+1.96	-11.69
1919	9.10		-1.78	-13.47
1920	15.00		+4.12	-9.35
1921	12.43		+1.55	-7.80
1922	10.18		-.70	-8.50
1923	13.42	12.02	+2.54	-5.96
1924	9.63		-1.25	-7.21
1925	14.44		+3.56	-3.65
1926	12.94		+2.06	-1.59
1927	10.90		+.02	-1.57
1928	11.21	12.41	+.33	-1.24
1929	15.07		+4.19	+2.95
1930	11.94		+1.06	+4.01
1931	9.24		-1.64	+2.37
1932	11.22		+.34	+2.71
1933	5.80	9.54	-5.08	-2.37
1934	9.88		-1.00	-3.37
1935	11.66		-.78	-2.59
1936	9.81		-1.07	-3.66

From this table the following conclusions can be drawn.

1. The precipitation for a single year, 1893, was 66 percent below the 46-year mean.

2. The precipitation for 1933, which probably has recently, or is now, affecting the spring flow, was 47 percent below the 46-year mean.

3. The 5-year mean for 1931-35 is 12 percent below the 46-year mean and 22 percent below the 10-year mean for 1921-30. Using the 6-year mean for 1931-36 instead of the 5-year mean for 1931-35 would make very little change in these percentages.

4. Although the period of time for which precipitation data are available is too short to draw very reliable conclusions as to precipitation cycles, there is an indication, both in annual precipitation figures and in the 5-year means, of a cycle of 30 to 40 years duration from the low of 1902 to the low of 1933 or from the low of 1893 to the low of 1933.

5. Although data for a 4-year period are not to be considered as entirely reliable for prediction, the figures for 1933-36 give some indication of an up-swing in the precipitation cycle.

6. Assuming that the accumulated precipitation was neither above nor below zero in 1892, the dry period from 1893 to 1905 produced a deficiency in precipitation of 19.66 inches, or nearly two years' normal precipitation, in a period of thirteen years. This indicates that the mean flow of the springs was 15 percent below normal for a period of 13 years. Allowing for several years "lag" in effect of precipitation on the springs, this period of low mean flow must have continued for several years after 1905. If the year 1933 occupies a position analogous to the positions of 1893 and 1902 in the precipitation cycle, it cannot be expected that the mean flow of the springs, exclusive of that developed by lowering their outlets, will return to normal within less than 5 years from the present.

7. The figures in the column, "Accumulated deficiency or excess", show that there was a period of high precipitation from 1920 to 1930 which overcame a deficiency remaining from the early part of the century and built up an excess. The largest excess figure in the 46-year period is that of 4.01 inches in 1930. It is certain that the water tables in the Casper aquifers stood as high or higher at this time than at any time during the preceding 37 years.

8. From 1930 to 1936 reduced precipitation brought about a change from an accumulated excess of 4.01 inches to an accumulated deficiency of 3.66 inches, or a loss of 7.67 inches. This is a loss of 11 percent from normal precipitation.

Population.- The decennial census gives no data on the population of Laramie since 1930 and is consequently of little use. The most reliable data available for conclusions as to percentage changes in population are those of the school census. Since university students make up a fairly large proportion of the population during most of the year, data on university enrollment are also pertinent.

TABLE II

School Census and University Enrollment

Year	School census	University enrollment
1920		493
1921		548
1922		708
1923		825
1924	2,476	907

1925	2,675	1007
1926	2,555	1132
1927	2,640	1203
1928	2,851	1280
1929	2,897	1177
1930	2,768	1334
1931	2,940	1402
1932	2,998	1238
1933	2,494	1191
1934	2,638	1410
1935	2,957*	1682
1936	3,175*	1899±

Both columns show a correlation of general increase, and a decrease in 1933. The percentage population increase from 1933 to 1936 would not form a fair basis for estimating water needs. This period was one of rapid rise from the depression. 1930 was not a boom year, nor had the depression yet been seriously felt. From 1930 to 1936 the school census shows an increase of 14.7 percent and the university enrollment an increase of 42.6 percent. The probable increase in population of Laramie in the last six years can be conservatively taken as around 17 percent.

Draft on reserves.**- The need for more water was apparently felt as far back as 1920. In this year Pope Springs was housed and its water diverted for municipal use. In 1924 the State Fish Hatchery was moved from Soldier Springs to Red Buttes in order to make the full flow of Soldier Springs available for municipal use.

*The official figures are 2,749 and 2,950. Mr. A. A. Slade, Superintendent of Schools, who kindly provided these data, informed the writer that the census for 1934 and preceding years included university students not residents of Laramie and under 21. They were not included in later years. In 1936, 225 of these students were omitted from the official figures. The writer made a corresponding percentage correction on the 1935 official figure.

**The historical information given here is taken from the following memoranda by E.K. Nelson, City Engineer: Development of Water Supply at Soldier Springs area. Feb. 18, 1937; Development of Water Supply at Pope Springs, Mar. 2, 1937; Notes on the History of the City of Laramie's Water Supply. Not dated. Written early in 1937.

The first excavation, lowering the outlet of Soldier Springs, was completed on April 9, 1929, at the end of a 25-year period of abnormally high precipitation. Thus it was considered necessary to begin drawing on underground reserves at a time when precipitation records indicate that the water tables in the Casper stood as high or higher than at any time since 1893.

On March 18, 1932, still before the 1933 low in precipitation, the Soldier Springs outlet was reduced again. On February 12, 1937, a hole was broken through Limestone 1 at the lower end of the Soldier Springs enclosure. Since 1929 the outlet has been reduced in elevation at least 10 feet. In addition, breaking through the limestone has had an effect considerably greater than that of a mere reduction in elevation of outlet.

During the housing of Pope Springs in 1920 the elevation of the outlet was reduced at least 3 feet. This did not become effective in cutting down water table level, because the general practice has been to keep the springs turned off by backing up water within the concrete walls of the house except during the irrigation period. On March 30, 1934, work of lowering the outlet pipe from the spring house to the extent of 3.3 feet was completed. The effective lowering of the outlet of Pope Springs is at least 6 feet and the last 3 feet was accomplished three years ago. From Pope Springs there have been flows of as much as 1,000,000 gallons per day. The present flow is about 50,000 gallons per day. Apparently the block of aquifers from which Pope Springs draw is nearly drained down to the level of the outlet.

Lowering of the outlet of City Springs to the extent of about 5 feet was completed less than a month ago, so recently that there has been, as yet, little effect on the underground reserves in the block from which City Springs are fed.

The various lowerings of spring outlets described above are equivalent to a lowering of at least 5 feet for all three springs. On page 13 of this report computations are given to show that this would draw from reserves at least 1,250,000,000 gallons, or 310 days days water supply. The assumptions on which these computations were made are accurate as to length of drainage area and very conservative, both in width of water tables and porosity. It is more likely that the draft on reserves is of the magnitude of 1 to 1⅓ years' supply. Most of this overdraft has been made since March, 1932. Approximately 20 percent of the municipal supply used in the last five years is water drawn from reserves.

SUMMARY

1. The Laramie municipal water supply is provided by three artesian springs fed by water from sandstones in the Casper formation. The natural flow of the springs is ultimately dependent upon the amount of precipitation which falls on the eroded edges of the Casper beds in an area of approximately 30 square miles. This area lies east of the line of springs and extends five miles eastward to the crest of the Laramie Range. The flow of the springs is independent of quick monthly variations in precipitation, but over a period of years the natural spring flow is proportional to total precipitation. Any additional flow obtained by lowering spring outlets represents a draft on underground reserves. Total reserves, and especially economically

accessible reserves, are limited.

2. Wells drilled into the Casper formation in the area west of the line of springs obtain water from the same catchment area as the springs. Water obtained in this way is a draft against normal spring flow. Drilling of municipal wells to augment the supply from the springs is justifiable only as an emergency measure to be taken at a time of great need, and should be avoided except under these conditions.

3. A small and uncertain amount of underground water can be obtained by drilling to the Satanka sandy zone east of the Forelle Ridge. Obtaining water from this source would involve expense of acquiring drilling rights, of drilling, and possibly of new pipe line and pumping. It is probable that the amount that could be obtained from the Satanka sandy zone would be too small to give more than temporary relief.

4. Unless some action is taken which will result in a considerable reduction in per capita consumption of water in Laramie, there is likely to be a seriousmunicipal water shortage in the near future. The reduction of elevation of exit of springs in the last five years has drawn from underground storage an amount of water equivalent to the total flow of the springs for one year in times of normal precipitation of 10.88 inches. Reduction of elevation of spring outlets has been carried so far that further reduction would be very expensive and might permanently injure the springs.

The total precipitation for the period 1931-36 was 12 percent below normal and 22 percent below the mean for the period 1921-30. The precipitation records for the period of subnormal precipitation from 1891 to 1905 give little cause to expect a return to normal or supernormal precipitation in the immediate future. Because of the distance which must be traveled by water from the place of entry into the sandstones to the place of exit at a spring or well, it is improbable that a single year of abnormally high precipitation would give an appreciable increase in spring or well flow.

The most reliable data available indicate that the population of Laramie increased about 17 percent from 1930 to 1936. There are no reasons to indicate that in the near future the population will remain constant or decrease.

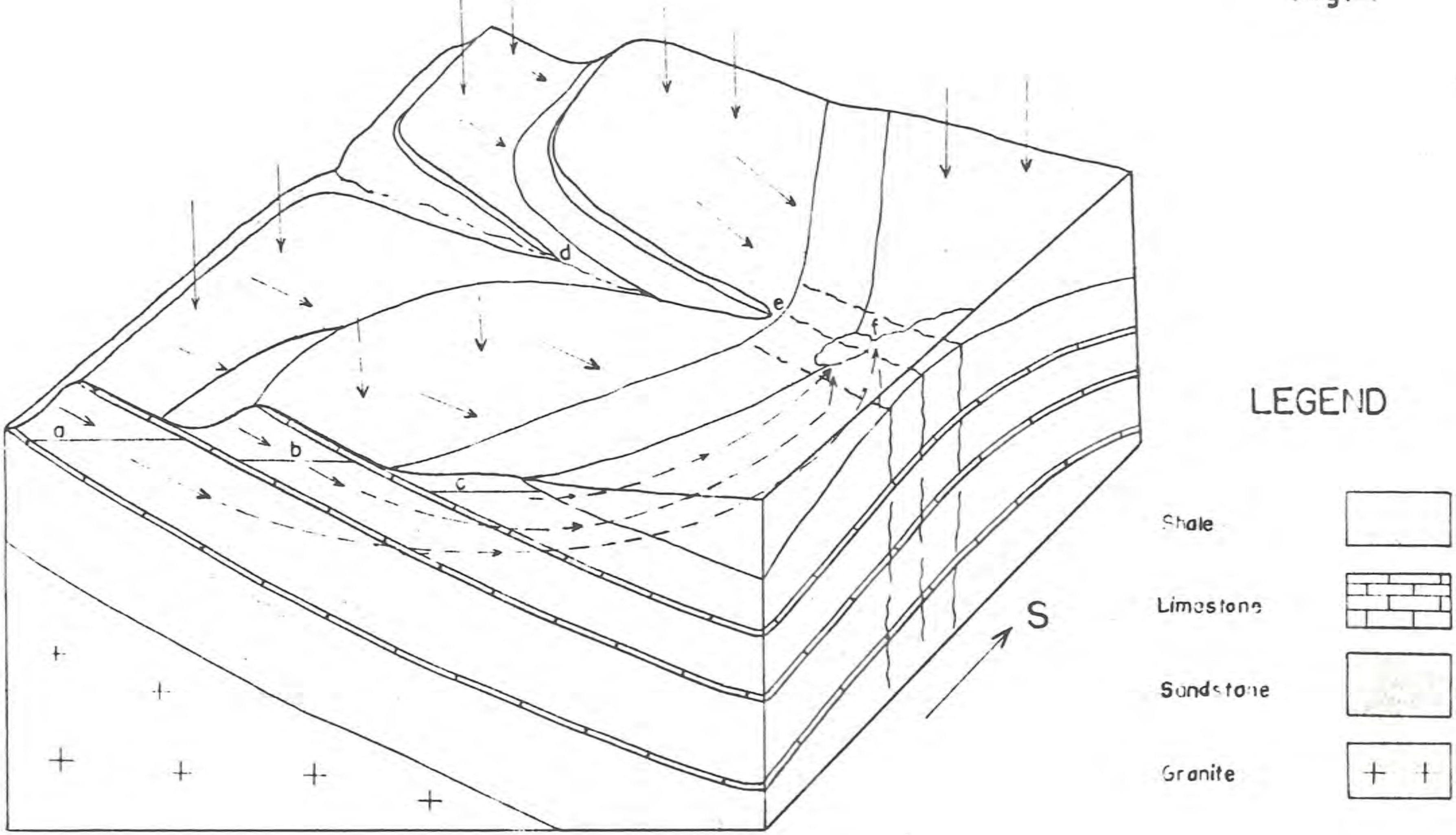
RECOMMENDATIONS

1. Steps should be taken (a) to reduce the per capita water consumption in Laramie, or (b) acquire an adequate supplumentary supply entirely independent of the catchment area from which the present supply is drawn, or both.

2. Even though one or both of the actions above is carried out, the present system should not be abandoned and construction work should be done at the various springs, which would make it possible to raise the levels of exit of the springs to their original elevations or lower them to their present elevations by a simple operation, such as opening or closing outlet valves. If the water tables in the Casper aquifers are again raised to their 1929 levels, either by cutting down the flow of the springs under control works while the supply is in use, or by accumulation of water during a period of years of high precipitation under control works at the exits, the sandstones will provide a reservoir capacity of considerably more than a billion gallons. From this type of reservoir there is no evaporation loss.

3. Flow meters should be installed on the three mains leading from the springs and adequate apparatus should be installed to give accurate measurements of the amounts of water which, during any interval of time, may issue from the springs and not flow into the mains. Accurate data on main flow, spring overflow, anc precipitation would provide an adequate basis for prediction of what normal spring flow could be expected at a given date a year or two in the future and give a basis for knowledge of what might be necessary to draw from a supplementary supply.

Fig. 1



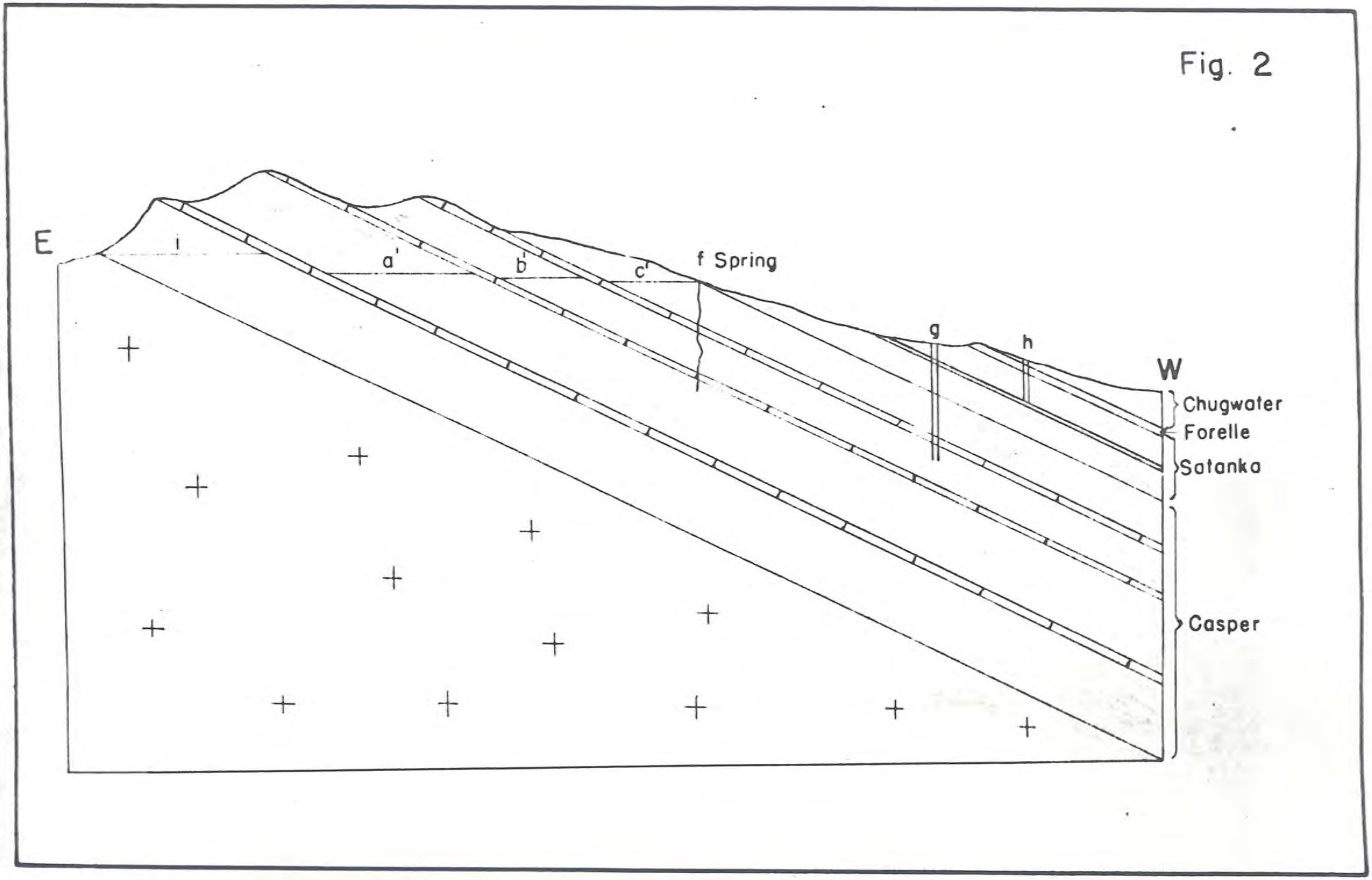


Fig. 2
E
i
a'
b'
c'
f Spring
g
h
W
Chugwater
Forelle
Satanka
Casper

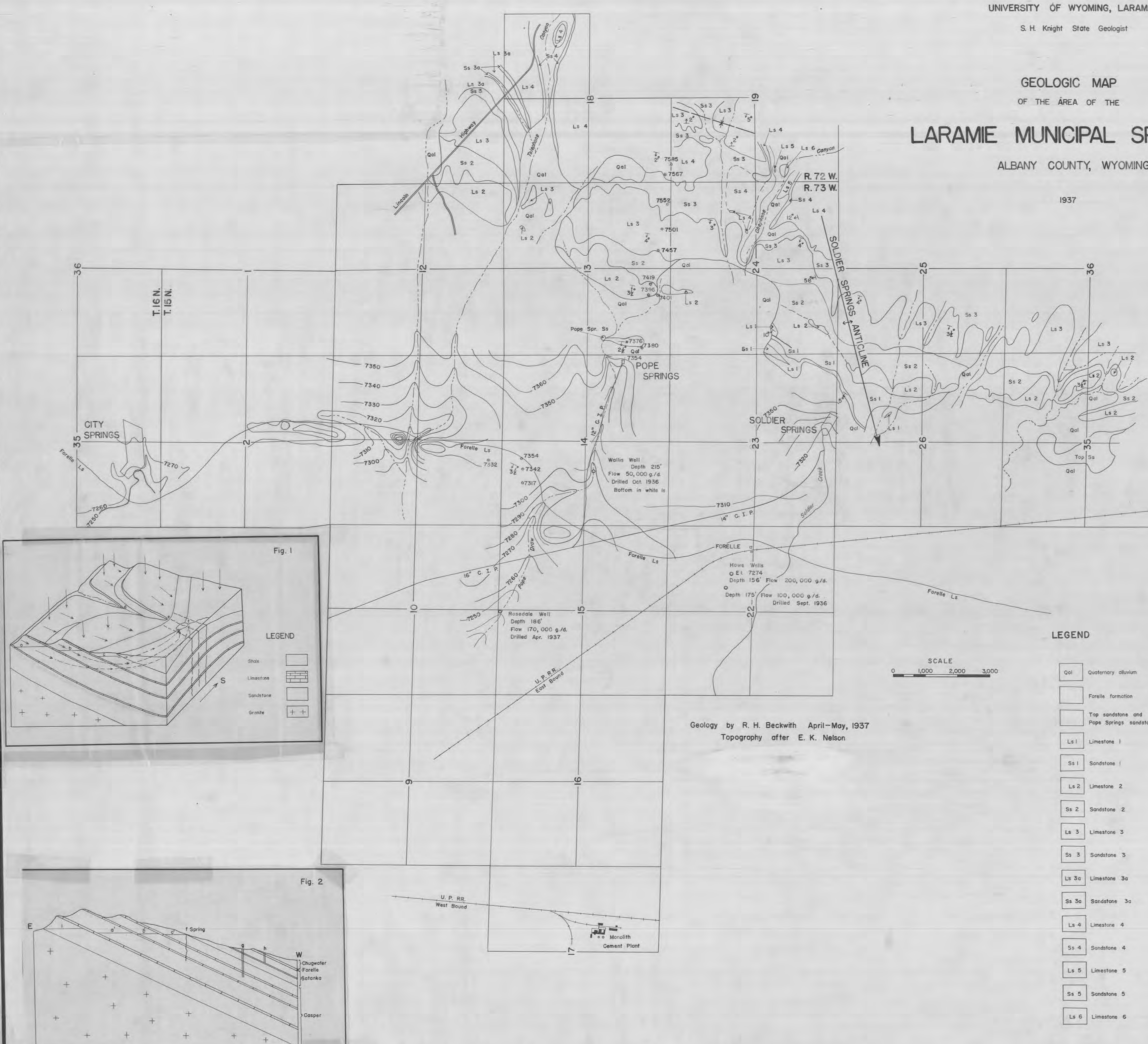
THE GEOLOGICAL SURVEY OF WYOMING
UNIVERSITY OF WYOMING, LARAMIE
S. H. Knight State Geologist

GEOLOGIC MAP
OF THE AREA OF THE

LARAMIE MUNICIPAL SPRINGS

ALBANY COUNTY, WYOMING

1937



SCALE
0 1,000 2,000 3,000

LEGEND

Qal	Quaternary alluvium
	Forelle formation
	Top sandstone and Pope Springs sandstone
Ls 1	Limestone 1
Ss 1	Sandstone 1
Ls 2	Limestone 2
Ss 2	Sandstone 2
Ls 3	Limestone 3
Ss 3	Sandstone 3
Ls 3a	Limestone 3a
Ss 3a	Sandstone 3a
Ls 4	Limestone 4
Ss 4	Sandstone 4
Ls 5	Limestone 5
Ss 5	Sandstone 5
Ls 6	Limestone 6

Geology by R. H. Beckwith April–May, 1937
Topography after E. K. Nelson