SOME ASPECTS OF IRRIGATION DEVELOPMENT IN COLORADO.

By Geo. G. Anderson.

Read before the Society, December 4, 1909.

It would be entirely impossible, within the ordinary limits of an address of this character, to present a comprehensive review of the salient features of irrigation development within our own borders, to say nothing of the entire arid region. There is so much, however, of vital interest in the work that has been and is being done within the state limits, that is typical of all of the arid region, that I will confine my remarks to that and to such of that as would seem to have a particular interest to a scientific society.

Through irrigation, agriculture has reached the first position among the industries of the state. That position has been acquired by many years of persistent and continuous effort. It has been the result of relatively slow, but very steady, progress, and, with all the evidences of extraordinary activity manifested in connection with irrigation development at this time, it will continue to be slow and steady, though, doubtless, more rapid than in the past, until such time as the possibilities of reclamation, by the application of all the available water within the state's limits to good land, upon reasonable financial terms, have been exhausted.

There is probably no more attractive sphere in which to exert one's energies than the reclamation of desert areas and the creation of new homes in the wilderness. It has for many an irresistible fascination, and the enthusiasm originally displayed in undertaking reclamation enterprises is sobered down gradually by the realization of the innumerable obstacles and difficulties that lie in the path to final successful achievement.
It has been my own observation, during the period of a generation to which I have devoted my energies exclusively in this field of enterprise, that every new period of activity has been followed by a check of greater or less duration, when it had appeared as if the development had gone too far, as if investments had been made that never would meet with adequate returns, that irrigation systems had been projected over areas that never could be really reclaimed, and that, finally, by gradual betterment of all the surrounding conditions, what seemed unfortunate ventures have been developed into successful undertakings, though the original projectors may have met with personal failure. And it is not improbable that similar experiences may await the present activity, though the present ought to profit by the lessons of the past.

It is not more than ten years ago since "irrigation securities were a by-word on the "street"—and the state was strewn with the wrecks of unfortunate and ill-timed ventures in irrigation development. I happened quite recently to find a copy of the Engineering Magazine of June, 1898, which contained an article by an engineer on "Unprofitable Engineering Projects in Western America," in which this statement occurs:

"In the richest and oldest irrigated farming community "of Colorado, only one canal in five has ever paid its expenses, "only one in eight has yielded any profit, and two out of five "of the largest canals have resulted in absolute loss."

These are strong statements, and may or may not have been true. I do not know the community referred to that had so great an accumulation of disaster piled upon it. But if it was the richest and oldest in the state, the assertion may be ventured that today these very unprofitable canal enterprises of 1898 have been developed into remunerative investments, remunerative, certainly, to the owners of lands irrigated by them, who, doubtless today own these enterprises.

For much has happened since 1898. The introduction of the sugar beet, alone, has practically revolutionized conditions, as to water, to crops and to values, there have been legislative enactments that have given an impetus to further develop-
ment; there has been the steady extension of storage reservoir construction, an increase in the actual duty of water and greater intelligence in the use of water, all of which have contributed to the existing agricultural prosperity of the State.

It is not too much to say that with these conditions, and within a reasonable time, the conservation of all the waters on the Eastern slope of the Rockies will be undertaken by the people of the state, if permitted free action, and there is hesitation only regarding the Western slope because of the meagre information of the water supply and the limitation of the area suitable for irrigation. The degree of success attending such development will depend, however, on the practical attention paid to all of the elements affecting the work, and the scientific investigation of every detail is more than ever essential. The consideration of some aspects of these details is what is proposed in this address.

I desire, as much as possible, to avoid statistics. As few only will be given as will be necessary to convey some conception of what has been done and what can be done.

It is not possible to state the amount of capital invested in irrigation in the state; some of it has probably been forgot or desired to be forgotten.

The agricultural produce for 1908 is, however, stated at $110,000,000. The value of the sugar beet crop is placed at $10,000,000 and of the fruit crop at $7,000,000.

According to the report of the water commissioners, there were over 2,000,000 acres actually irrigated in 1908, of which 45,476 acres were in fruit, 487,541 acres in alfalfa, 64,037 acres in potatoes, 151,428 acres in sugar beets, and 85,291 acres in field peas.

It is well nigh impossible to get even an approximate idea of the length of canals. Some effort to ascertain it has been made at various times by the State Engineer's Department through the water commissioners, but such reports have never been full or complete. It is probable, however, that there is between 10,000 and 12,000 miles of main canals in the state, and probably as great a length of laterals and distributing ditches.
In the last, the fourteenth, Biennial Report of the State Engineer, it is stated that the area actually irrigated in 1908 was 2,013,680 acres, and that the area that could be irrigated was 2,878,795 acres. These areas are estimated, are obtained from the Water Commissioners, who in turn probably obtain them from the owners or agents of canals and ditches (there are no reports at all from some districts), are not to be regarded as absolutely accurate, but are probably a reasonable approximation. Just what is meant by the "area that could be irrigated" is not clear, though it probably means the additional area under existing canals and ditches not yet cultivated, but susceptible of irrigation by means now in operation.

It has been estimated by a well informed authority on irrigation matters that, recently, 500,000 acres have been added to the irrigable area of the state by the construction of canals and reservoirs and that probably a further increase of 500,000 acres can be made by the more economical use of the immediately available water supply. Both these statements would indicate a limitation of the possible irrigable area to approximately three million acres.

Researches in the records of the State Engineer's Office reveal that from the beginning of 1900 up to the present time, there have been 6,042 filings made for canals and ditches, with total appropriations of 742,571 cubic feet per second, and 3,709 filings for reservoirs with a total capacity of 33,449,437 acre feet. Of these, there have been filed since January 1st of this year, 1,022 canals and ditches with total appropriations of 146,821 cubic feet per second, and 656 reservoirs with a total capacity of 9,237,934 acre feet, which latter quantity exceeds by nearly 50 per cent the highest previous record of any year in the period.

Upon the modest duty of 80 acres per cubic foot per second, in direct supply, the total appropriations on the ditch filings would be sufficient to irrigate an area of 59,405,680 acres additional to the area now irrigated and the total capacity of the reservoirs, upon the duty of two acre feet per acre,
would add a further area of 26,724,718 acres to the agricultural domain, in a total amount somewhat in excess of the total area of the state.

It is very probable that a large number of the ditches are contemplated for the filling of the various reservoirs filed upon and should not, therefore, be considered. For the present, however, it is only intended to give some indication of what the present active movement would mean, if there was real intention and real water behind all these filings.

Mr. F. H. Newell, Director of the United States Reclamation Service, has recently said that "if all the run-off waters of the arid region could be conserved and employed in irrigation, the total area might, perhaps, be brought to nearly 60,000,000 acres."

According to these filings, this state can alone furnish that irrigable area.

The significance of these figures may be more apparent if considered somewhat in detail and in relation to districts that are more or less familiar.

In District No. 3, alone, which is the Poudre River and its tributaries, there have been, in the total period mentioned, 156 ditch filings aggregating 21,507 cubic feet per second, and 203 reservoir filings with a total capacity of 1,250,944 acre feet. In the present year only, there have been filings made for ditches aggregating 7,119 cubic feet per second, while the maximum discharge of the stream, by official records, has been about 6,000 cubic feet per second, and the filings made for reservoirs have aggregated a capacity of 610,702 acre feet, practically as much as the total of all the previous reservoir filings since 1900, while the mean annual discharge of the stream, as shown by the records, has been 341,660 acre feet. The filings of this year alone are thus greatly in excess of the ordinary annual discharge of the stream, without taking cognizance of the prior appropriations adjudicated, which, in average years, are themselves in excess of the mean discharge.
In 1902, a year of phenomenally low flow, it was reported that the waters of the Poudre River were so carefully administered that practically no water escaped from it into the main stream and these conditions were approximated again in 1908.

In District No. 1, which comprises the South Platte River and its tributaries below the junction of the Poudre River, since 1900, the aggregate capacity of reservoirs filed has been 2,616,204 acre feet, while the mean annual discharge has been about 720,000 acre feet, which amount the reservoir filings for 1909 alone, 563,273 acre feet, closely approximates.

In Districts Nos. 8 and 23 combined, which comprise the South Platte River from Denver upstream to the headwaters, since 1900 there have been 195 filings for canals and ditches with total appropriations of 19,765 cubic feet per second, and 123 filings for reservoirs with an aggregate capacity of 3,166,078 acre feet.

The maximum discharge of the stream ever recorded was slightly in excess of 5,000 cubic feet per second, while the mean annual discharge has been about 345,000 acre feet.

Some two years ago, in connection with an inquiry of local importance, it was estimated that there was then available for storage on the river about Platte Canon, after all existing prior appropriations were supplied, approximately 16,000 acre feet on the normal annual discharge of the stream. Since that time, the Antero Reservoir has been completed with a capacity of 58,000 acre feet from one branch of the river.

Compare these conditions with filings for over 3,000,000 acre feet!

In one year alone, 1907, the reservoir filings amounted to over 1,000,000 acre feet.

In District No. 7, which comprises Clear Creek and its tributaries, during the three years of 1907, 1908 and 1909, there have been 35 reservoir filings made, with a total capacity of 164,856 acre feet. The normal annual flow of the stream is approximately 200,000 acre feet, out of which, of course,
must first be provided the amount previously appropriated, which more than exhausts the normal supply, except, perhaps, for the brief flood periods.

These detailed examples are probably sufficient to clearly indicate that, if filings and appropriations count for anything, there can be no doubt of the intention and desire to conserve all the available waters of the state by our own efforts, and that the enthusiasm of the period has carried us, already, greatly beyond the limitations of the water supply.

It is doubtless true that a large percentage of these filings will never mature into actual appropriations by diversion and application to beneficial use, but while the actual cost of a filing is insignificant, the acts preceding it, of surveys and investigation, represent some expenditure of capital and energy and there may follow the effort to secure capital for investment upon a foundation that may be insecure, if the known limitations of water supply are even approximately informing.

And even though actual construction does not follow upon the act of filing, these filings stand upon the records, with practically no limitation so far as that office is concerned, nor until adjudication of appropriations occurs in the particular districts. The effect of such standing upon subsequent appropriators, with serious intention of following up filing with construction, is plain enough, the situation may become so puzzling to an engineer examining for probable investors that he would simply run away from it. It is doubtless true that some of these filings are mainly for the purpose of harassing legitimate efforts.

As the law stands, the State Engineer's Department has no authority to reject any filing made, if it complies with the rules and regulations of the office. That some such authority should be given seems essential. Some states in the arid region have a regulation, that, if it is the judgment of the State Engineer that the stream upon which a filing is offered, has already been over appropriated, he may enter such opinion on the face of the filing. To that, there is considerable objec-
tion in that there might be hindrance to enterprise by arbitrary individual judgment. And instances have been known where such regulations prevail, of closing the doors for long continued period to such filings by reason of presumed over appropriation, suddenly opening them to one or more filings, and as suddenly closing them again to the next.

It must be very apparent, however, that if the state would seek to avoid the obloquy attaching to litigation almost certain to follow upon continued appropriations on streams wherein no waters be, or upon the much more disastrous investments of large sums in enterprises based upon such, some action must be taken, some authority given to some State Department.

Unfortunately at the present time, such authority would not be exercised upon full information, as the knowledge of the stream flow is totally inadequate.

In the Fourteenth Biennial Report, it is stated that: "The expenses paid for guagings at the above (guaging) stations (14 in all) by this office during the past two years (1907-1908) amounted to $129.41, the amount paid to the observers amounted to $562.14, making a total of $691.55."

There may have been co-operation with the United States Geological Survey, and there may have been additional expenditures for hydrographers, etc., though neither of these appear, but there is elsewhere, in the same report, the statement of an expenditure of $6,065.55 on the guaging fund, with a balance on hand of $3,949.83, which fund is the accumulation of fees charged for filings made.

In the same two years, there were 1,199 reservoir filings made, with total appropriations of 11,567,512 acre feet, and 1,873 ditch filings for 293,714 cubic feet per second.

The lack of real information is due solely to the failure to provide sufficient appropriations to carry on the necessary work. In that respect, the state has been almost criminally negligent, and it is difficult to conceive why, year after year, so little has been done in what so vitally affects the best interests of the state. Every succeeding State Engineer has
pleaded for further and increased appropriations, co-operation has occasionally been had with the Geological Survey, to some benefit, and yet, the best and most complete records have been furnished by private parties, to be frequently repudiated, so ungracious can we be and so much of a fetish do we make of government reports, as such.

The last Legislature voted $20,000 for stream gauging, after very strenuous efforts on the part of a very few. And it was agreed that the Federal Government would appropriate a similar amount for the same purposes in Colorado. The appropriation was subsequently placed in the fifth class, with the result that the State Engineer will not receive any part of that appropriation until about the end of next year, if at all.

The Federal Government is not much more generous or better advised in appropriations for this fundamental necessity. Recently $100,000 only has been appropriated annually for stream gauging for the whole of the United States.

To quote Mr. Newell again:

"If all the run-off waters of the arid region could be conserved and employed in irrigation, the total area might, perhaps, be brought to nearly 60,000,000 acres. This is very uncertain, however, as our knowledge of run-off is confined to only a portion of our streams and is incomplete."

Much is said in these later days of the conservation of our national resources, within and without the law; to breathe anything not strictly in line with the views of certain noisy advocates is to be classified as "undesirable citizens."

The Reclamation Service has, according to reports, expended since 1902 something in excess of $50,000,000, and, impoverished, is seeking for further advances of from $10,000,000 to $30,000,000.

One hundred thousand dollars has been for some time the annual expenditure for hydrographic work throughout the whole of the United States, and only a portion of it in the arid region, where our knowledge of run-off is confined to only a portion of our streams and is incomplete.
What may result is fairly well indicated in the following illustration:

The Hondo project, in New Mexico, was undertaken for the irrigation of 10,000 acres of land, depending upon a reservoir with a capacity of 40,000 acre feet, having a watershed area of 1,037 square miles, with an average annual rainfall of 15 inches.

The construction was authorized in November, 1903, and was completed early in 1907, at a cost of over $362,000.

The following extract is from the Seventh Annual Report of the Reclamation Service for the year ending June 30, 1908:

"Although the construction of this project has been finished for practically two irrigating seasons, there has not been sufficient water available to warrant the secretary in opening the project, owing to an unprecedented drought on the watershed. Such water as has been available has been used on the lands without having been stored in the reservoir. There are between 1,500 and 1,600 acres in cultivation during the season of 1908. During the first part of the season there was sufficient water for the irrigation of this acreage, but by June 30 there was no available water and the crops were very much in need of it. * * *" 

"Even in face of the drought, the owners have kept up good spirits, and the price of land has held up remarkably well. This condition is, perhaps, partially due to the fact that the artesian wells, in the Roswell artesian basin, * * * have been showing a gradual decline in pressure, and some of those situated on the higher levels have ceased to flow. Many predict, and it seems a safe prediction, that the entire artesian district will fail, and many farms now in a high state of cultivation will have to depend on pumping for a water supply. Since the supply may be exhausted, flood storage is the only source of relief, and the Hondo Reservoir will find ample use."

Mark Tapley must have written that, though Mark did not exult in the probable misfortunes of his neighbors.
It must be exhilarating to know that the land owners, who are under contract to the Government to repay the expenditure of $362,000, by lien upon 10,000 acres, their homes, and who have not had sufficient water to irrigate 1,500 or 1,600 acres for two successive years, "have kept up good spirits," even though these good spirits are partially due to their prediction of failure of the well supply. How, in such event, a reservoir that has not secured any supply for two successive years, can then find ample use must remain among the mysteries.

It may have been more in the public interest to have postponed the expenditure of $362,000 and spent a comparatively small part of it in obtaining reliable information of the sufficiency of the water supply, at the same time keeping the land owners from obligations of $36 per acre, which, without water, it will certainly be impossible for them to return to the government.

The repetition of such experience is certainly to be avoided, but that such may occur within the arid regions within the state of Colorado, with the existing knowledge of our stream flow is just as certain as that 20 or 30 years ago, much capital was invested and many canals constructed on the Poudre and South Platte Rivers, depending on the direct flow, that proved unremunerative and inoperative from lack of such water supply, which economic waste could have been avoided by more extended information.

And more extended hydrographic work is required than merely stream gauging.

There is practically nothing known, in a scientific way, of the loss by evaporation, in reservoirs, in open channels, alike in river and canal beds. Some spasmodic observations were made under the guidance of the Agricultural College, but have apparently been discontinued.

Continuous hydrographic work, extending over a long period and probably over several seasons, is required in connection with the storage of water in mountain reservoirs and their subsequent transportation down the bed of a stream to
be subsequently diverted possibly many miles below. There are numerous cases where these conditions exist, several on the Poudre, the Antero and Cheesman Reservoirs on the Platte, and three on the Arkansas, to mention only a few.

The law permits the use of the stream for such transportation, subject to deduction for loss in transit, the loss to be ascertained by the Commissioners of Irrigation for the district, or, if there are no such commissioners, by the County Commissioners of the county in which the water is taken out for use.

So far, the loss has never been determined.

On the Poudre River, I am informed, no loss is charged at all, nor is there on the Platte.

On the Arkansas River, the Twin Lakes Reservoir, located about Granite, is charged 10 per cent loss from transporting the water thence for about 180 miles. That was the result of a "guess," without any observations of any kind.

Recently, the Clear Creek Reservoir, also near Granite, seven miles further down stream, commenced transportation of water eighteen miles further down stream than the Twin Lakes. For the extra distance, an extra loss of 3 per cent was charged, arrived at by due consideration of the Division Engineer without measurements; in other words, also guessed.

These determinations are not satisfactory, apparently, to water users interested, neither to reservoir companies nor direct users. Litigation is inevitable, is said to be pending.

There should be no good reason why either should be taxed with the cost of such determination, very evidently a prolonged and costly task. To the reservoir company, it would seem an added burden on enterprise, while the direct users have actually had their rights disturbed. The results obtained by either would, in any event, be unofficial, and clearly it is the duty of the state, a duty which surely should have been performed long ago. There has been no money available—and possibly the loss will continue to be "guessed" for some time to come.
Similar observations are likely to be required for some probable conflicts that at present loom large in the distance.

There are an increasing number of diversions of water from the western to the eastern slope being proposed and constructed. Murmurs of objection have been heard; so far as the Grand River drainage is concerned, there is, doubtless, sufficient water in that stream to care for the irrigable lands along it in Colorado, but the Reclamation Service may require all the surplus for Arizona, California and Mexico, as was seriously advanced a few years ago. It would appear highly probable, however, that resistance will be made to the further diversion of water from the Laramie to the Poudre, as Wyoming has already announced an intention to prepare for a contest.

The long drawn out controversy with the government over the use of waters in Colorado in the San Luis Valley, as that may effect the construction of the Engle dam in New Mexico, stirred the last Legislature to make an appropriation of $15,000 for the purpose of making special investigations as to the stream flow, etc.

This appropriation, probably, met the same fate as the appropriation for stream gauging and may be available sometime—after the dam is constructed.

For many reasons, much more extended observations of "return inflow" or seepage on the streams should be made. They have heretofore been conducted in a dilettante fashion. The conclusions made from them have either been premature or misleading, and clearly need revision.

This feature merits more than incidental reference here, if for no other reason than that a subject of its great importance, upon which so much has been written and said, upon which it is frequently attempted to base legal rights and to claim that a much more widely extended use has been made and is being made of the waters of the streams than would appear possible, has not been given sufficient consideration on scientific principles. In that respect, indeed, it has been almost as completely neglected as stream gauging,
to which it is allied, and, upon insufficient data, it would appear that conclusions and deductions have been drawn that are at least misleading.

It is not to be denied that such return flow exists, in varying volume, in various streams, and apparently not at all in some of them. It is plainly visible in the lower reaches of the Poudre and South Platte Rivers and there undoubtedly occurs in sufficient volume to aid in the administration of the waters among the various appropriators by the state officials. It is doubtful if it is increasing actually or in proportion to the increase of the irrigated area or if its total amount is as great as is frequently stated, as from one-third to one-half of the water applied on irrigation, as, for example, in the South Platte River, where it undoubtedly exists in greater volume than elsewhere in the state.

Beginning with 1885, on the Poudre River, measurements have been made, usually in the fall of the year, to ascertain the amount of this flow. In 1889, similar measurements were commenced on the South Platte, and later the field of observation was extended to a number of streams throughout the state. Except on the South Platte, there have been several breaks in the continuity of these measurements.

In 1896, a report was made by Professor Carpenter, issued as Bulletin 33 of the Experiment Station. Subsequently, in the 10th and 11th Biennial Reports of the State Engineer, he reviewed the results up to 1902, and it is understood that another bulletin is in course of preparation.

In the bulletin, certain conclusions are arrived at and repeated in the 10th Report, with the remark that they need but little modification. It would appear that the later measurements call for some modification.

These measurements have been made, ordinarily, in only one day in each year, and usually in October or November, when the inflow is naturally the greatest, though there is evidently a difference of opinion about that. And they are not accompanied by accurate and continuous data on such matters as the land area irrigated in the districts tributary to the
streams observed, or the amount of water applied in irrigation each year.

It has been concluded that the increase of such inflow is greater as the irrigated area is greater, and that the increase is approximately proportional to the irrigated area.

On the Poudre, an increase of 80 per cent of the irrigated area in the past twelve years has yielded an increased flow of 24 per cent, while it now requires 1,282 acres to yield an inflow of 1 second foot in place of 700 acres in 1896.

On the upper reaches of the South Platte, the return shows either an actual decrease or an increase below that due to the increase of the irrigated area.

On the lower South Platte, the gain in return flow is also less than the gain in the irrigated area, though it is still a high return.

On the Arkansas River, in its lower section of 208 miles from Canon City, the return inflow in 1897 was 331 second feet, in 1907 250 second feet, in 1908 292 second feet. The acreage irrigated is not given, though it is known to have greatly increased.

The following are a few of the results stated in relation to area irrigated in 1906:

- Big Thompson...........1 sec. ft. to 1,500 acres
- Boulder Creek ..........1 sec. ft. to 1,862 acres
- St. Vrain Creek.........1 sec. ft. to 3,430 acres
- Clear Creek ............1 sec. ft. to 7,031 acres

Considerable portions of the irrigated lands in Clear Creek drain directly to the South Platte.

With these great differences, it would seem that other influences affected the return inflow than the area irrigated.

It is concluded that the inflow is practically the same throughout the year, that it is more in summer and less in winter, because principally of the effect of temperature on the soil. That is a conclusion which cannot readily be accepted. Common observation indicates otherwise.
It is unfortunate, in that connection, that of all the combined measurements, only twelve have been made at any other season of the year than in the fall, and from these, it cannot be concluded that the inflow is greater in the summer, on the whole, it seems to be much less.

Indeed, there would seem to be a period of inflow, extending from October throughout the winter months to the following March or April, in accordance with the natural conditions which would seem to affect their operation.

The mean surface flows of the South Platte River at Denver and at the mouth of the Poudre River would rather indicate that.

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The irrigation season extends from April to October inclusive; the normal high flow period from April to June inclusive. The volumes stated at the Poudre River are the volumes after the demands for the upstream irrigation have been supplied. In August and September only are the discharges of the down-stream station less than that of the up-stream, while the great increase in the flow at the down-stream station in the non-irrigation season and in the month of October is the strongest indication that the bulk of the inflow occurs in these months.
The passage of seepage waters through the soil is very slow, so that it may take years for the seepage from outlying lands to reach the draining streams.

That may account, to some extent at least, for the erratic and seemingly unresponsive volume of the inflow in relation to the amount of surface flow.

1900 and 1905 were years of high surface flow, yet the return inflow was either normal or below normal. 1902 was a year of phenomenally low flow—the return inflows were below, in some instances greatly below normal. There are those who contend that the return flow results from a careless and excessive application of the water in irrigation; that if the water were applied in an ideally perfect manner, only so much would be used as would be demanded by the growing plants and by the unavoidable evaporation from the soil, and there would be no such evidence of return flow. Theoretically, such a contention is perfectly correct, though it overlooks the consideration that much also depends upon the porosity of the subsoil, a consideration which is equally lost sight of in the claims that the amount of the inflow bears a proportionate relation to the area irrigated. It seems, too, that another feature is lost sight of which has the plain name of overflow, in which the irrigation is of the most profuse nature, mostly on bottom lands for grass crops, and being close to the river, the surplus waters, after the soil is soaked, returns to the river on the surface.

That there is and has been a careless and wasteful application of water in irrigation is undoubtedly true; it is undoubtedly true of those districts where the amount of return inflow is greatest. In 1895, for instance, the amount of water used on 106,000 acres in the Poudre Valley was 260,000 acre-feet, an average duty of 2.45 acre-feet per acre.

In 1906 the two upper divisions on the South Platte used 377,741 acre-feet on 109,474 acres, an average duty of 3.45 acre-feet per acre.

The gradual decrease of the return flow—or at least the absence of any marked increase with the increased area is evidence of the improving methods of irrigation, largely
through the increased reliance upon stored waters in reservoirs, with the assurance the user has of a supply when it is actually required, he is less prone to its lavish use, especially as the experience is that the moderate use produces better practical results.

In the Bulletin, there is the conclusion that the amount of seepage is slowly but constantly increasing, which the later measurements, except on the South Platte, fail to show.

On the conclusions that as much as 30 per cent, or from one-third to one-half of the water applied in irrigation returns to the stream and is used over again, there would be some surprise at the result, if it were not made plain that such conclusion is arrived at upon the assumption that the inflow measured on one day of the year is the inflow for every day of the year. That cannot be accepted as a correct assumption, certainly not until fortified with the results of continuous observations spread throughout the year. If it were a correct assumption, it would be true that in 1895, on the Poudre River, the return flow was 30 per cent of the water applied in irrigation. But it would not be true in 1906, 1907 and 1908, when the return inflow was the same or less than that of 1895, while the irrigated area had doubled and there is no available information as to the amount of water applied.

If it were a correct assumption, then in 1905, the return inflow at the State Line on the South Platte River exceeded the water applied in irrigation in all the divisions of the stream and all its tributaries with the exception of the Poudre River.

There is not much room for doubt as to the cause of this underflow, if there were no other evidences of it than the gradual increase of the elevation of the water table. It is the usual experience in the districts brought under irrigation that water is found in wells in the unirrigated sections only at great depths, there is a steady rise after the surrounding district has been irrigated. The water applied in irrigation, not actually absorbed by growing plants and by evaporation, fills the subsoil and gradually drains into the stream.
It is well known that there has been less development of storage reservoirs on the upper reaches of the Platte, which yields the greatest amount of return inflow than almost anywhere else.

As this return inflow is undoubtedly greater, whenever it does exist in any volume, in the fall and winter than at any other period, and the greatest demand for an irrigation supply is during the summer, it is evident that only by storage can full advantage be taken of this feature of the results of irrigation, whether avoidable or not.

It is extremely fortunate that ample opportunity exists for storage development in the district, whether the greatest return inflow occurs, the lower reaches of the Platte, and such opportunity is certainly being fully taken advantage of.

I have dilated at probably undue length upon this feature, but there are two other points I would state, at the risk of your patience, which seem to me very important:

Just as it is vitally essential to extend the scope of the gaugings of stream flow, so is it necessary to extend the observations of the return inflow, to determine, if possible, the relative quantity of inflow at all seasons of the year, if for no other reason than to make accurate conclusions of the real quantity to be depended upon, if it is to be depended upon at all.

Some of our courts lean to the recognition of this return inflow as a necessary consequence of irrigation, and, in a broad sense to regard it as a beneficial use, led, perhaps, to that belief by the belief that such return inflow is of the relatively high proportion heretofore deduced.

It is observable that in applications for the transfer of water rights of early appropriations on the upper sections of streams to the lower sections—to which, otherwise, there seems to be general and well founded objections in principle, there has recently crept in a tendency to recognize this feature of return inflow, and it has been argued, and in some cases within my knowledge, it has been decided that the lavish use of water in the upper sections of streams is beneficial in the
sense of creating this return inflow, and that in cases where the duty of water has been as low as 30 acres, in one case 20 acres to the cubic foot per second, and where it would be difficult to demonstrate the return of one-tenth of the water applied.

Upon the Rio Grande River, in connection with the development of the Engle dam by the Reclamation Service, there is likely to be serious conflict over the use of the waters of that stream by appropriators in the San Luis Valley in Colorado, and it behooves the State to be preparing for that apparently inevitable contest. If any reliance is to be placed upon the amount of return inflow developed in the valley, there are only very few observations on record, four to be exact, and from these only cold comfort can be extracted. The total gain within the State is shown to be comparatively insignificant, and there are sections where an actual loss occurs.

In consideration of the possible area reclaimable by irrigation, the duty of water that can be secured and maintained is a controlling factor.

There has been a steady approach to a reasonable and high duty of water, influenced largely by reliance upon storage, improved conditions of cultivation, greater skill and intelligence employed in the use of water, and the increasing realization that moderate use produced actually greater pecuniary results. Such advance in improved methods will continue until the limiting duty has been reached, which is, briefly, the least quantity of water required to produce the best crop obtainable with good farming.

Thirty years ago, it was considered that a long step had been taken in establishing in water contracts a duty of 1 cubic foot per second to 55½ acres—stated as 1'44 cubic feet per second to 80 acres. I have every reason to believe that that duty was arrived at and concluded as the lowest reasonable duty then obtainable, by the highly scientific method of striking the average of opinions, stated in statutory inches, offered by three practical farmers!
The "duty" in contracts was enlarged to 80 acres per cubic foot per second, and later, in some cases, to 100 acres, and frequently it was expressed in acre-feet per acre.

It has been shown that, in 1895, the actual duty in the Poudre River was 2·45 acre-feet per acre, and, in 1906, on the South Platte River, 3·45 acre-feet per acre. These figures are from the Water Commissioner's reports, which are not necessarily reliable on such matters.

Unfortunately, there is not much of a more scientific nature to guide in the determination of this feature. The Department of Agriculture has devoted some effort to a determination of the duty under certain varying conditions. In Bulletin 86 on "The Use of Water in Irrigation," Professor Elwood Mead writes as follows:

"The observations made by observers show that the duties obtained vary from 1 acre-foot per acre irrigated to the use of over 15 acre-feet on an acre, but these wide and seemingly eccentric variations in the quantities used were the results of manifest causes. Where water was distributed through well-built ditches and used by careful irrigators, there was a surprisingly close agreement in results, even in widely separated localities."

Where measurements were made on small canals or laterals, eight tests, in as many states, from Nebraska to California, showed the duty to range from 1·82 to 2·60 acre-feet per acre, with a mean of 2·37.

"Where the water was measured at the margin of the fields, there was a still higher duty than where measured at the heads of the laterals. The table shows the duty obtained where all losses in distribution were eliminated and nothing "but the water actually spread over the fields was measured."

The duty ranging, in five tests, from 7 to 1·78 acre-feet per acre. Then follows a table showing the number of acre-feet used per acre where measurements were made at the canal headgates and include the losses from seepage and evaporation, showing an average of 5·47 acre-feet per acre from 7 tests in
Arizona, New Mexico, Utah, Colorado and Idaho, with the comment:

"A comparison of the duties at canal headgates with those obtained when the water was measured where used, will show that more than twice as many acre-feet were required where the water was measured at the headgate as where measured at the place of use, or, in other words, the losses in the canals from seepage and evaporation amount to more than one-half the entire supply."

That latter conclusion was doubtless correct, but, without any actual measurements to verify that, the recent observation and experience have been that the canal losses are now much less, that they gradually reduce as the canals age, though, with local variations.

In the various Reclamation Service projects, the duty of water is estimated variously at from 1 1/2 to 5 1/2 acre-feet per acre per annum, the higher figure, and the lower duty, on the Yuma project in Arizona, California, and the lower figure and higher duty in Oregon and Montana. The duty of the Gunnison project is stated in the old-fashioned way, of 1 cubic foot per second for 80 acres.

Recently, and especially since storage reservoirs have so largely entered into irrigation operations, the duty has been established, it may be safely stated, as the estimate of requirement in each case, certainly not by any closely observed actual results.

Still more recently, in case of various reservoir enterprises in conjunction with new irrigation districts, the duty has been placed in contract agreements as low as 1 acre-foot per acre, in some cases at five-eighths acre-foot per acre and that delivered at the reservoir.

These are bold efforts towards an economic use of water, unsupported, it would seem, by any previously obtained actual result. If it is possible to carry 1 acre-foot per acre from a reservoir, through a canal of average length, bearing all the losses in transit, distribute it over land similar to that in the immediate vicinity and therefrom produce a remunerative
crop, there still remains a very considerable extension of the irrigable area beyond anything yet contemplated.

If it is not, and the water user has to acquire more water at high price in order to produce a crop, his commercial position may be jeopardized, and if so, a general readjustment may ensue, for upon the farmer's prosperity, and upon that only, can irrigation be made successful, financially.

The principal legislative act which has given a stimulus to irrigation development is the Irrigation District Act passed originally in 1901 and amended in 1905.

The act gives such districts the power of quasi-municipal corporations, the right to construct or to purchase canals and reservoirs, to operate them, to issue bonds for these purposes, such bonds constituting a lien upon the real estate within the district.

It practically provides municipal ownership, and the water-users are by it enabled to combine for their own direct interest, the management being entirely in the land-owners and water-users themselves. With ordinary care, the best results are likely to follow upon its extended adoption it is probable that, as ex-State Engineer Jaycox said in his latest report, it will form the best method yet developed for rapid, economical and successful development of the arid portions of the state.

It has been the observation that the water-users themselves, in community canals, have proved the best and most economical managers of such properties. It is stated that the management of the irrigation district has not yet been so successful, perhaps because the method is new, but mostly, apparently, because in the selection of directors, there is the introduction of practical politics.

As was more or less inevitable, there has been some dissatisfaction with the organization of some of these districts, with the creation of bond issues and with the disposal of these in payment for the construction of the canal systems. The law provides that the bonds shall not be sold for less than 95 cents on the dollar, the practical operation is the disposal of
these bonds to contractors for the construction of the works at such prices and upon such terms as can be arranged.

The provisions of the act have been applied to conditions probably never contemplated by its framers. A large block of land is owned by three persons, by far the greatest holding in one individual who also owns some water rights, both land and water being undeveloped. These three persons vote the land into an irrigation district, create a board of directors, themselves in fact, sell from themselves to themselves the water rights at remunerative, if not actually exorbitant, prices and issue bonds against the district so created, created, too, in strict compliance with the law. (That was not in Colorado.)

Though but a short time has elapsed since the enactment of the law, some further amendments are very evidently necessary.

It is reported that, so far, no irrigation district has defaulted in interest payment upon bonded indebtedness, which, of itself, adds to the credit and the security of further bond issues of that character. To further establish that and to protect the settlers themselves, it is essential that some form of examination and approval be made by the state. That, primarily, should be directed to the features of the permanency and adequacy of the water supply, in view of some of the conditions which have been outlined here, and also, it seems to me, to the duty of water to be established. On the latter point, it may be contended, that if the settlers are ready to accept and to contract for a given supply of water, it becomes their personal concern, even if the opinion of experience may be that such amount of water, if dependable, is not in itself sufficient for satisfactory or even necessary results. But individual failure in such cases may have far-reaching consequences, and it may be necessary to protect inexperienced citizens against their own acts for the benefit of others that may be similarly placed.

Further, some form of state supervision of the construction of the works, in relation to their permanency and adequacy, may be advisable. With the appearance of paternal-
ism, at first blush, it is surely possible to conduct such supervision in a manner to be beneficial to both settler and bond investor.

Some arrangement should be made whereby government land held under homestead and desert entries that would otherwise be incorporated in such districts could receive the benefit of the organization without individual agreements, and some further arrangement whereby the public lands could also be incorporated in such districts—and without the combination of a district under the Carey Act, to be later referred to.

Under the provisions of the Irrigation District Act, a very great increase to the irrigable area has occurred in the past seven years. In the lower Platte Valley alone, approximately 200,000 acres have thus been “reclaimed,” with another under construction embracing 70,000 acres.

In the Arkansas Valley, the Otero Irrigation District has been the means of resuscitating an enterprise to reclaim 20,000 acres, while another is contemplated with 75,000 acres to be irrigated. In the Montezuma Valley 55,000 acres are embraced in a new district.

In the Grand Valley, four districts are either projected or under construction that will embrace 55,000 acres.

And there are several large projects in the vicinity of Greeley and Denver that embrace over 200,000 acres additional.

These are not intended to exhaust the list of such projects, but merely to indicate something of what has been done.

The Carey Act passed by Congress in 1894 is another enactment which has stimulated irrigation progress, and ranks with the District Act in providing means for economical and successful development.

It empowers the Secretary of the Interior, with the approval of the President, to contract and agree to patent to states having desert lands, not to exceed 1,000,000 acres of such lands under certain conditions.

The Colorado legislature in 1895 accepted the conditions and the grants of land to the state under the provisions of
the act of congress and provided for the manner in which the irrigation, reclamation, occupation and disposal of the same should be carried out.

The settlers upon such lands ultimately become the owners of the reclamation works constructed by the companies operating, who enter into contract with the state for the carrying out of the works and the delivery of water, secured against the lands by lien.

These projects are thoroughly safeguarded, the State Board of Land Commissioners requiring an examination and report by the State Engineer upon the adequacy and permanency of the water supply and the feasibility of the enterprise, while the General Land Office, acting for the Federal Government, makes similar independent examination, and no segregation of lands occurs until these have been submitted and accepted.

In one feature, the Act requires amendment—a temporary segregation of the lands should be made at the initiation of the works by the company contemplating such improvements, to prevent the filing upon lands in anticipation of such development—the act providing for the segregation and incorporation in the resulting benefits, only of public lands not settled upon.

Until recently, until the present year, only three companies had taken advantage of the act in this state, seeking to reclaim about 38,000 acres. During the present year, applications have been made for over 200,000 acres.

In other states, the total applications have exceeded 3,000,000 acres, Idaho alone representing over 1,000,000 acres.

Something should be said regarding the management of the affairs of this very far-reaching development by the State Department, but space is limited, and there are some other features that call for extended comment.

The great work overtaken by the State Engineer and his department does not seem to be realized nor properly appreciated by the state. The appropriations for the office have always been entirely inadequate and the state has been fortu-
nate in securing competent officials for insufficient remunera-
tion, with no relation to the burdens and responsibilities of
the office, to say nothing of its dignity.

The time is rapidly approaching, if it has not already ar-
rived, when the duties should be divided, the work of roads and
bridges put in a separate department and the State Engineer
be charged with the irrigation administration solely, the duties
of that alone being sufficient for the whole time and individual
attention of one man. It might be hoped that the time has also
arrived when the tenure of the office will not be limited by the
life of one or other political party.

The office of Division Engineer is also inadequately re-
munerated, and its importance minimized. There are five di-
visions in the state, presided over by officials who are paid
$1,500 per annum and expenses, who care for the division of
waters in accordance with appropriations, among irrigation
systems that annually add over $110,000,000 to the wealth of
the state!

Bearing in mind that the present day development has
been the outgrowth of the primitive methods of the unskilled
pioneer of fifty years or more ago—the earliest irrigation in
the state can be traced back to 1834—it is inevitable that
much of the actual construction work is not upon what may be
strictly regarded as economic or scientific lines.

There has been an unnecessary duplication of canals and
ditches, the early irrigator tapped the stream to suit his own
immediate necessities, the later promoter extended the ditch
and enlarged into a canal. Structures were originally and al-
much of necessity of a temporary character, because of limited
means and the more or less speculative nature of the enter-
prises.

Gradually these were of a more permanent character,
wooden headgates gave place to stone and steel, and the timber
flumes were replaced by steel flumes, or by siphons of either
wooden-stave or concrete. The enhanced land values and the
increased security and revenue from the enterprises warranted
the more permanent work and that has been stimulated by the
general type of construction adopted in the public works in the charge of the Reclamation Service, though the private enterprises may not yet be able to wholly adopt the more elaborate methods, nor prepared to admit the necessity for them, especially as the return of capital so expended may not be as certain as would appear in the public works, where the settlers are under contract to refund all the total cost of the government works.

With some features of these more elaborate structures, there has arisen lately some anxiety, and to one particular class some extended reference may be made.

It has been observed that failures have occurred in concrete structures, in the form of crumbling or disintegration, due, presumably, to the action of alkali present both in the soil and in the water and resulting from chemical reactions occurring between the sulphates in these waters and the cement.

It is well known, of course, that alkali is present in greater or less amount in the soil of the arid region. In the disintegration of the rocks the minerals have been broken down into mineral salts, which have remained as soluble salts in the soil. The rainfall and the drainage of the region are both insufficient to carry these salts out of the soil through the subsoils and eventually into the streams and rivers, as is the case in the more humid regions.

The salts are largely the sulphates of lime, magnesia, soda, alumina, iron and potash, and the carbonates of soda and potash. Of these, the sulphates only may prove injurious to concrete, and as the shales, of the Dakota formation, are known to be rich in alcalis and to be common throughout the arid region, it may not be surprising that the results already observed should have occurred and that failures will continue, unless means are taken to resist the actions in operation.

A good many, if not all, of the projects of the Reclamation Service and of all other irrigation projects are located in alkali regions. The attention of the service engineers has so far been directed to failure of concrete structures on two only of these projects—one in Montana and one in Wyoming.
That may indicate some special peculiarity of the local soil and is somewhat similar to the well-known fact that the action of sea water has been destructive to concrete in certain localities and not in others.

Investigation is being made by the chemists of the service, so far the report has not been published, but some of the conditions were set forth by Mr. Jewett, the cement expert, in a paper read before the American Society of Testing Materials in June last, which may be briefly summarized.

On the Sun River project in Montana, disintegration occurred in a number of small structures, such as pipe culverts, partially submerged in the small streams carrying the drainage of the surrounding country.

In some of these, which had only been in place for three or four months, the parts under water were much softer than the parts above, but the greatest evidence of disintegration was shown at the water surface.

Microscopic examination showed minute crystals which disintegrated on exposure to air, becoming a fine powder. The crystallization exerted an expansive force, similar to the action of freezing, though much more severe, one culvert being described as having no strength at all, being like so much mud and sand at the water level.

An analysis of the water showed the principal ingredient to be magnesium sulphate—in the quantity of 6,870 milligrams per liter, leading to the conclusion that the effect of this water in disintegration is similar to sea water, in which magnesium sulphate is the principal agent in disintegration of concrete.

Professor Headden has, at various times, issued bulletins on the subject of alkali in the soil and in the water, and in the latest, No. 132, "The Destruction of Concrete by Alkali," he gives an account of rapid deterioration in cement tiling, in which the results and conclusions are strikingly similar to the Montana case.

The tiling had been laid from eight to nine months. Disintegration had extended so that one sample was simply a white putty-like mass, mixed with sand, with nothing re-
motely suggestive of concrete; in another the interior portions had wholly decomposed, leaving an outer and inner shell in fairly good condition, while a third had been attacked on the inner side, leaving the mass of the tile fairly sound outside of the zone of decomposition, which was sharply defined.

Professor Headden points out that "the most active agent in decomposing concrete is the sulfuric acid of the sulphates carried in solution and that solutions of gypsum have been shown to act detrimentally on concrete by forming with the tri-calcic aluminate a sulfo-aluminate, and finds that the water acting on these tiles, whether ground water or drain water, was very bad, one sample containing 1252.6 grains per imperial gallon of which 493.5 were sulfuric acid, with an extremely large proportion of magnesia, while the other contained 542.3 grains per imperial gallon, with 42.31 grains of magnesic oxid or 7.8 per cent. of the total solids. And he concludes that there is an ample supply of these substances present which are known to act deleteriously upon cement, chiefly the sulphates, a portion of which is magnesic sulfate, while there is so much sodic carbonate present that its action cannot be neglected.

The action on these tiling seems to be similar in Colorado and Montana.

The features of construction may not be readily compared. In the Montana case, Mr. Jewett points out that the work was done by force account under the direct supervision of the Service Engineers and not by contract and was thorough and substantial. In the Colorado case, there is not much information, the sand used was quite pure, the proportion 5 to 1, and the individual masses must be small and readily attacked by solutions of salts capable of reacting with the cement.

Both investigators found the decomposing action to be similar to that of sea water, in which magnesia sulphate is the principal agent.

In summary, Professor Headden concludes that the cement has been deprived of silicic acid and that a relatively
large amount of lime has been removed. The ferric and alum-
inic oxids have been reduced to about one-half as much in the
decomposed cement as in the original. The sodic sulphate, and
particularly the calcic and magnesic sulphates present in
the ground water will act on the tri-calcic aluminate, forming
the sulfo aluminate which crystallizes with 60 molecules of
water and is soluble. In the water free decomposition prod-
uct, sulphuric acid is over 20 per cent and carbonic acid over
12 per cent, as compared with about 1 per cent each in the
original product, while magnesic sulphate is over four times
greater in the decomposed than in the original product. And
there is the final conclusion that:

"The action of the ground waters seems to have been one
"of chemical change, converting the lime of the cement into a
"sulfate and carbonate accompanied by the removal of silicic
"acid, alumina and lime and totally destroying the cohesiveness
"of the concrete."

Bulletin No. 69 of the Montana Experiment Station deals
with a very striking illustration of deterioration in the sewers
of Great Falls, which has been frequently referred to, and has
been the subject of much discussion and comment. A very
clear exposition of the conditions is presented, which would be
quoted, if time would permit, but for the present, the conclu-
sions only will be set forth.

The examiners in that case found that the destruction and
disintegration of the concrete did not occur from the adultera-
tion of the cement, nor from the quality of the materials used,
that the principal cause of the failure of the bricks in the work
was their unfitness for sewer construction, though a limited
chemical or physical action of the alkali salts may have been
a contributing cause, and that the action upon the cement was
chemical action, that the destructive agent came from the out-
side and that the disintegration of the cement could not be
charged to any action arising from the sewage or gases from
the same.

There is no chemical investigation of the action on the
cement and its alteration, that is to form the subject of a later
bulletin, and the analyses in the report show that the maximum disintegration occurred where the greatest percentage of alkali showed in the soil and that the ground waters were leaching out the alkali from the soils and depositing the salts along the sewer.

The report concludes with the opinion that the use of cement for sewers and other structures in alkali soil is inadvisable where it is not possible to drain all ground waters from the exterior of the structure.

Such drainage was entirely effective in a structure somewhat similar to the Great Falls sewers—an outlet from the reservoir known as Lake Loveland. There the conditions were of comparatively large quantities of drain water showing in the trenches during construction and complete and effective drainage was put in merely to facilitate the prosecution of the work and not because of any recognized or anticipated action of the water, known to be heavily charged with alkali—upon the concrete. The structure remains intact and in perfect condition after fifteen years.

Other instances of rapid deterioration and disintegration might be quoted, did time permit, notably a reservoir spillway in the Arkansas Valley. There the concrete had been placed upon a foundation of shale rock, from which oozed the alkali water. No provision had been made for under-drainage, and about two years after construction, the interior mass of the concrete could easily be removed and pulverized in the hand. On the first passage of water over the spillway, the lower section was washed out as thoroughly as if it had merely been sand.

These instances clearly show that there are new problems in construction wherever such conditions are likely to be met, or rather old problems under new conditions.

It is quite evident that the effects of alkali upon concrete are similar to those of sea water, with some differences, as these in themselves differ in various localities, as evidenced in the destruction of sea works on the northeast coast of Scot-
land, and no resulting damage on the Atlantic coast, where, apparently, the conditions are similar.

That may be due to difference in the character of the sand, and on that point reference may again be made to Mr. Jewett's investigations.

In the sand used in the Sun River project, the engineers reported that there were evidences that the only supply readily available contained alkali or some substance making it chemically active and assisting in the disintegration of the concrete. Chemical analysis showed excellent results from physical tests, but the alkali content was about 3 per cent, corresponding to about 15 or 20 per cent of feldspathic material, with a considerable percentage of limestone, making it altogether likely that this sand would be more readily acted upon by the influences tending to disintegrate the concrete than a sand of a more highly silicious nature.

Means of overcoming sea water action are fairly well outlined, though as competent an authority as Feret says:

"No cement or hydraulic product has yet been found "which presents absolute security against the decomposing "action of sea water."

While Michaelis, on the other hand, long ago made certain recommendations including, physically, a dense concrete surrounded by an impermeable layer, and chemically, the use of cement rich in silica and as poor as possible in alumina and ferric oxide, and the use of substances which render the mortar, in its external layers at least, denser and more capable of resistance.

There is no suggestion here that the problem is an insurmountable or even a difficult one, it imposes, however, greater discrimination in the selection of material for various structures and of ingredients composing the structure, and, in all probability, a different and differing quality of cement than has been heretofore manufactured for general use, and in addition to the external application, the possible incorporation in the mass itself of an impervious material or coating.
A few—very brief comments—should be made on the feature of the soils of the arid region, in their suitability for irrigation and in the action of alkali, in soil and water alike, as the practice of irrigation is continued.

That feature merits extended comment as it has attracted extended investigation, but such must meantime be deferred.

Secretary Wilson, several years ago, in the course of a newspaper interview, made the apparently sensational statement that—

"Many of the rich and beautiful valleys of this great section are being ruined by improper irrigation. The improvident and improper use of water is not only dangerous, but destructive, for it brings out the alkali and ruins richly fertile lands. I regard this question of proper irrigation as one of the most important presented for solution to the country."

In a recent issue of the *Engineering Record* there is an article entitled "The Supplement to Irrigation," by which is meant "drainage."

Fresno county, California, is referred to as a section where "Irrigation accomplished wonders, but has brought with it another problem. Although the canals are still in serviceable condition, and the water supply is the same as ever, "only dead stumps mark the place where once valuable orchards and vineyards flourished, comfortable farm houses "are falling into decay, and stately California palms stand like "sentinels over deserted carriage drives."

Utah, Oregon and Washington are referred to as having similar, if not so striking experiences.

It is deemed certain that where the ground water rises nearer than 4 feet to the surface, capillary action draws it to the surface, when the water evaporates, leaving the salts on the surface. These clog the pores, increasing capillary action and forming a hard crust upon the surface, rendering agriculture impossible. Even without the presence of alkali, the raising of the water table prevents new roots from reaching proper depth, and rotted old roots developed before the pores of the soil became saturated with water.
Similar conditions exist in Colorado, principally along the bottom lands, with little natural drainage. These lands, also, are detrimentally affected by the over irrigation of the uplands, and the leaching out from them of the salts in the soil.

The Bureau of Soils, of the Department of Agriculture, has devoted considerable effort to the investigation of the analysis of soils and of the waters of the arid region—have issued numerous bulletins, in nearly all of which attention has been forcefully called to these conditions, and the work is being continued and extended.

The State Agricultural College, by Professor Headden, has devoted much time to various sections of the state where the trouble is of a serious nature.

In Farmers' Bulletin No. 88, the conditions of the Montana case which prompted Secretary Wilson's utterance, are fully set out, as well as the general conditions surrounding injury from alkali, attributed solely to over irrigation, to the trans-location and local accumulation of salts by means of seepage waters, and to the imperfect drainage facilities in the compact gumbo soils and the inability of the excess of salts and of seepage water to escape.

Under drainage, on extensive and comprehensive plans, is recommended. These may be expensive, the Grand Island drainage near Sacramento cost $1,100,000, and the proper drainage of the San Joaquin Valley will require many millions.

To be effective, the drainage of the seeped lands in the Poudre Valley, for instance, must be comprehensive—individual effort did not and cannot secure the necessary results. It is necessary that legislation be enacted for the creation of drainage districts, and this will probably be effected in the immediate future.

Drainage, however, may not wholly solve the difficulties that now present themselves—and even that must be accompanied by restricted and moderate irrigation of the uplands.

Crop rotation is partially effective where drainage is not wholly so, and that is being practiced on well considered lines in the northern part of the state.
One other feature should be commented on, that of settlement on the irrigable lands following upon the completion of the works to supply water.

In the earlier ventures in Colorado, that proved a difficult problem, and many enterprises undoubtedly failed by reason of the long interval between completing expenditures and receiving returns. Today the conditions are different. There is ready market for irrigable lands with anything approaching an adequate water supply attached.

It is understood that some difficulty is being experienced in securing settlers under some of the government enterprises, while adjoining private enterprises are swamped with land buyers.

That may be due to lack of colonization organization by the Government; even throngs of land-seekers need direction. It is much more likely due, however, to dissatisfaction with and misunderstanding of the terms under Government projects.

The Reclamation Act, in effect, provided that the cost of the enterprise was to be refunded to the Government in ten annual instalments, secured by liens upon the lands.

The Reclamation fund was to become revolving, the completion of one enterprise was to provide the funds for undertaking the next.

There has been a very wide difference between the estimated costs and the actual costs, for which there is no occasion for surprise, under all the circumstances. The engineers occupied a rather enviable position, in that respect, that Uncle Sam was behind them with an unlimited check book, unlimited until quite recently, and the Government was, apparently, in a more fortunate position than private companies launching upon such enterprises, in at least securing the return of all the money invested, although without interest.

Recently, however, conditions have changed; the reclamation fund has been exhausted, it has not commenced to revolve nor shown any violent symptoms of doing so, while the settlers have manifested rather strong objections to footing all of the bills.
At a recent convention of water users' association, among which the water users in the Gunnison project are included, a resolution was adopted and presented to the Senate Committee on Irrigation and the Reclamation of Public Lands, in which it is set out that relying upon the law—which plainly says that the estimated cost of the project shall be returned to the reclamation fund—and relying on the statements of the engineers, they voluntarily signed contracts and pledged lands and homes therefor, and now find that the actual cost is charged against the land, and that, therefore, it is resolved that they should pay only the estimated cost.

If the estimated cost only is repaid, in some cases, the reclamation fund will sustain a serious loss; if the actual cost is to be repaid, in some instances, it will severely tax the best resources of the settler, and, in brief, the Reclamation Service is at the stage where so many of their predecessors have been discouraged, where disbursements are concluded and returns should flow in.

In conclusion, I hope it has been made clear that with the greater opportunity provided by suitable legislative enactments, the wider field and its better conditions, and utilizing the experience of the past with greater skill, ability and purpose, a very great extension of the irrigable area of the state is possible with security and ample return to the required investment, but that it devolves upon the state now to provide, as a sure foundation for that stable structure, a much more extended and intimate knowledge of the available water supply and such further adequate and effective methods of supervision as shall safeguard the real interests of its citizens, capitalist and farmer, homebuilders both.

Remarks by Mr. Fellows. (By Letter). Mr. Anderson's paper is so comprehensive that it seems as though little could be added. I desire, however, to enlarge, briefly, upon a few of the points touched upon by Mr. Anderson.

The first point to which I wish to call your attention is in connection with what was stated by the author regarding the enormous number of filings and the vast and largely imagin-
ary water supply that has apparently been filed upon. One feature of these filings was not very clearly brought out, this being that many of the filings that are made are duplications of still earlier filings upon projects and water supplies. Under our filing law, the State Engineer, as has been stated, is obliged to accept any filings, provided they comply with certain conditions as to form; consequently, any number of people may file upon the same project, and there are frequently dozens of filings upon a single proposition or source of water supply, where but one project, when constructed, will cover the entire ground.

For example, I am familiar with one proposition upon which at least four preliminary filings, which are authorized by our law, have been made, these four preliminary filings having been again followed by a still greater number of more or less perfected filings upon the same proposition. In this case, only one project can be constructed, the filings, however, showing under different names applications for perhaps ten times the available water supply, and this might easily be increased to one hundred, or infinity, so far as any control by our law is concerned.

It would seem that here, too, the law should be remedied. Under the filing laws in some of the other irrigating states, as for example, Wyoming, Idaho, etc., but one application can be received for a given water supply to cover a given tract of land. When such a filing is properly made, a permit is granted to utilize the said water supply in the method described, and the state stands back of that permit, no one else being allowed to enter the field for a certain period, which period is made long enough for the work of construction to be accomplished.

It would seem as though some such method should be adopted in this state, also, thus preventing the wasteful expenditure of money, both in engineering and litigation, by parties who think they have some little show of securing a desirable project "by hook or crook."

The author has referred to the fact that some fifty millions of dollars, or more, have been expended by the Reclamation
Service without sufficient preliminary investigation as to water supply. Some may have been led to infer that the Reclamation Fund, or at least a considerable portion of it, should first have been used in the making of investigations as to this feature. Anyone familiar with the Reclamation Law, however, will recognize the fact that the law itself does not authorize the use of this fund in any other way than the examination and reporting upon such projects, and subsequent construction, and when one bears in mind the immense pressure, political and otherwise, that is brought to bear upon the officers of the Reclamation Service, to compel them to construct projects in each and every state and territory entitled to the advantages of the Reclamation Fund, the fact will at once be recognized that it would have been extremely difficult, if not entirely impossible, for the Reclamation Service to have taken any more time in the preliminary investigations of projects than was actually employed. If, however, Mr. Anderson's contention is that it would have been better if the law had been so framed that the Reclamation Funds could have been used, at least to a considerable extent, for the purpose of studying our water supply, I would certainly agree with him.

In this connection, it may not be out of place for me to call attention to the difficulty of obtaining accurate hydrographic data. The Geological Survey, handicapped as it has been by small appropriations for the purpose, has still done a great amount of work along this line, for which it is not given sufficient credit. It would appear that, in a matter so important as is the compilation of hydrographic data, engineers generally, who, individually, as Mr. Anderson has stated, have private data sufficient to form a vast collection if it could be brought together, would be willing to co-operate in the making of such a collection, so far as it was in their power. I well remember, however, how, when I was compiling a water supply paper upon the water resources of Colorado, for the Geological Survey, I sent out several hundred circulars to all of the engineers of the state, published also in all of the newspapers, asking for such data as engineers could give me on
this subject, I received just one reply, this being a post card from Del Norte, asking me in turn for some information, but furnishing none. The natural inference is that the fault is not altogether with the Government.

I desire to call attention, also, to the importance of an extension of the topographic work of the Government. This is almost as important to the irrigation engineer as the hydrographic work in the determination of water shed areas, topographic conditions, physiography, etc. It is extremely important to every engineer to have as accurate and complete topographical data as possible. It would appear, then, that anything that can be done to increase the appropriations for this purpose would be energy well expended.

With reference to the statement made by the author concerning the duty of water used in the Uncompahgre Valley, with reference to what is known as the Gunnison Tunnel Project, it might be of interest to know that several hundred letters were sent out to users of water in that region, asking them for detailed information as to the methods adopted by them in irrigation, and the amounts of water used in the various irrigations. From all of the replies received, a number were selected as representing the best thought amongst the farmers of that region, and a generalization was made from that end and all other obtainable information, which led to the belief that three and a fraction acre feet per acre should be provided in normal years for use upon the mesa lands of at least a large portion of the valley. It was also estimated that at the periods of maximum use, approximately eighty acres could be irrigated by each cubic foot per second, and the dimensions of the canals were, therefore, estimated with this fact in mind. In this way, I presume the idea of the irrigation of eighty acres per cubic foot per second was given out.

While I am in a reminiscent mood, it might be of interest to you to learn, also, the way in which the “guess” referred to by Mr. Anderson, as to the probable loss by evaporation and seepage in the passage of water from Twin Lakes to the head of the Bob Creek or Colorado Land & Water Company’s
canal was made. The owners had just finished the construction of their reservoir, and were proposing to turn water down for use in the Bob Creek canal. Already some water had been turned down, and the question arose as to the deduction that should be made to cover losses in transit. The owners, naturally, contended that but little water would be lost, while conflicting interests, naturally, held, on the other side, that the losses in transit would be very great. The Twin Lakes people were threatened with an injunction, which would probably have prevented their obtaining relief at any time during the season. On July 16th, 1900, Mr. McCune, the then State Engineer, was requested to settle this question, if possible, and, not being able to look after the matter himself, at the time, he asked me if I would handle it for him, although I was then in the Government employ, and not in that of the state. I consented to this arrangement and went to Pueblo that night on that account. On my way down I made some computations, taking into consideration the probable increase in area of the channel of the Arkansas River, caused by turning in an additional two hundred cubic feet per second at a low stage of the natural flow, the increased velocity due to the same cause, the length of time required for the passage of the water from the Twin Lakes to the head of the Bob Creek canal, and other relative matters, and came to the conclusion that a deduction of ten per cent would be as fair as anything that I could determine upon. Arrangements had already been made at Pueblo for a midnight meeting of the parties at interest, and I told them at once that if they would agree to abide by my decision, I would act as referee and make the necessary measurements for ratings, but if they would not agree to this, there was no use in our wasting time over the matter, as I had other things to do. They finally consented to abide by my decision, the understanding being that the arrangement was temporary and for that season only, to allow time for more thorough investigations. I accordingly proceeded at once to Twin Lakes, and made my measurements there, and announced as my conclusion that for the present a deduction of ten per cent should be
made for the amount turned out. I did not, for a moment, antici-
pate that this conclusion would be allowed to stand perma-
nently, as it was clearly stated that the arrangement was
merely temporary, and it was so understood by all parties. Mr.
Anderson is quite right, however, in saying that the conclusion
was, in a certain sense, "a guess," but so are many engineers'
conclusions which, however, have been made after taking
into consideration all relevant facts, and it would appear that
no one as yet has found time to make the necessary investiga-
tions, as the guess has been allowed to stand, up to the present
time. I have never had anything whatsoever to do with the
matter since that time.

Still another matter in this connection, upon which I would
like to go upon record, and which relates particularly to some
present aspects of irrigation, is that intense cupidity of too
many capitalists, brokerage firms and banking houses, which
tempts and leads them to finance irrigation projects without
merit. It is, no doubt, a strong temptation to a banking house
to take bonds of an irrigation district, for example, without
particular regard as to whether the project is worthy of being
financed or not, providing only that the banking house can se-
cure the bonds at a low figure and quickly dispose of them at a
great profit. No student of present aspects of irrigation in
this state can doubt that projects are being financed which
can never be successful, and where, in all probability, bonds
will eventually fail of payments. I need not go into the details
of the dangers that threaten irrigation and irrigation engin-
eering, as they are familiar to most of us. It has today been
reported to me, however, that the bonds of one district had been
taken at 37 cents. Such a proceeding could hardly happen
excepting where the bonds were being exploited merely for
the money that could be immediately made from their sale,
and without reference to the legitimacy of the project. Cer-
tainly, some safeguards should be drawn around the forma-
tion of irrigation districts, when it is so easily legally pos-
sible to form districts without merit, such as are a number
that have recently been formed in this state.

Denver, Colorado, December 18, 1909.

By the Secretary.

During the past year the proceedings of your Society show that nine regular meetings were held, with an average attendance of 34'1, and that ten papers were presented and read. The papers read, with their titles and authors, were as follows:

"The Main Tungsten Area of Boulder County, Colorado," by Professor Russel D. George.
"Tungsten Mining and Milling," by Mr. Victor G. Hills.
"Notes on the Magnetic Separation of Tungsten Minerals," by Mr. Henry E. Wood.
"Preservation and Utilization of the National Forests," by Mr. Smith Riley.
"Some Recent Advances in the Science of Physics," by Professor Oliver C. Lester.
"Ore Dressing in the United States and Mexico," by Mr. Harry A. Guess.
"The Smoke Question," by Mr. Thomas L. Wilkinson.
"Notes on Some Mineral Springs," by Dr. William P. Headden.
"Some Aspects of Irrigation Developments in Colorado," by Mr. George G. Anderson.

The titles and authors of the above papers stamp their value and their importance, and scientific recognition is further demonstrated through the deep interest created among the members, as shown by the valuable and thoughtful dis-
cussions following their reading, and by the demand for them from publishers, universities, scientific societies and individuals.

No regular meeting was held in January, this date being taken up by the annual dinner. The heated months of July and August were also without regular meetings. The lowest attendance at any meeting was 22, in May; and the highest was 53, in February. The average for the nine meeting was 34.1. As compared with last year, the lowest being 19 and the highest 61, the average being 37.6.

During the year 26 new members were elected and two reinstated, making an increase of about 11 per cent. as against 12 per cent. for 1908. Our membership list shows a decrease of 43, made up as follows: Three by death, six by resignation, and 34 being dropped from the roll. If we deduct the nine members lost by death and resignation, our net growth would be less than 8 per cent.

The Executive Committee feels that the community is not fully advised as to the usefulness of this Society, the value and importance of the papers presented and discussed, the utility of our technical library and the advantage to students of our mineral and geological collection. It is incumbent upon the members to make known these advantages, and if each member will bear this in mind, a more rapid growth is assured.

Those claimed by death were: General William J. Palmer, who died March 12th; Mr. Branch H. Giles, who died August 29th; and Mr. Jacob Harman, the date of whose death we do not have.

The Executive Committee has manifested a deep interest in the welfare of the Society and has given thoughtful consideration to all matters brought up at its meetings. During the year it has held eight regular sessions and two special meetings, besides holding a number of informal discussions. The records show the average attendance at these meetings to have been 6.4.
REPORT OF THE EXECUTIVE COMMITTEE

There has been no effort made to add new volumes to the library or to increase our museum collection. It being thought advisable to postpone such efforts until we are permanently housed and we are assured of a desirable and fixed home.

I submit the following report of the Library Committee:

Books added to the library during 1909 were as follows:

By Purchase—
Mineral Industry, Volume 17.
The Copper Hand Book, Volume 8.

Gifts—Bound Volumes—
Bureau of American Ethnology, Bulletins 34, 39, 41 and 42.
Annual Report of the Smithsonian Institution for 1907 and 1908.
Biennial Report of the State Historical and Natural History Society of Colorado for 1907 and 1908.
Mineral Resources of the United States, Parts 1 and 2, 1907.
The Yukon Territory, Its History and Resources, Geological Survey of Canada.
Australasian Association for the Advancement of Science, Volume II.
Mining and Smelting Magazine, Volumes 1-7, inclusive, presented by Mr. E. Le Neve Foster.
And numerous unbound copies presented by members of the Society.

Our exchange list remains the same as last year, with the exception of two additions, viz., The Cleveland Engineering Society and The Pacific Miner.

The number of visitors to the library during the year was 1,289, as against 1,776 in 1908.

The Executive Committee wishes to acknowledge the loyalty and zeal of the Assistant Secretary, Miss Rebecca M. Riddle, in the performance of the duties of her office. She has had complete charge of the library and museum and has rendered efficient aid to the officers of the Society and has conscientiously and faithfully performed the business pertaining to her position.

W. A. JOHNSTON,
Secretary.
REPORT OF THE TREASURER OF THE COLORADO
SCIENTIFIC SOCIETY FOR THE YEAR 1909.

Denver, Colorado, December 18, 1909.

Receipts:

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<tr>
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$3,186.39

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$2,792.75

Cash on hand: $393.64

Respectfully submitted,

J. W. RICHARDS,
Treasurer.

Approved:

CHARLES W. COMSTOCK,
FRANK E. SHEPARD,
VICTOR G. HILLS,
Auditing Committee.
THE ADDRESS OF THE PRESIDENT, FRANKLIN GUITERMAN.

GENTLEMEN OF THE SOCIETY:

I am sure that you agree with me in the conclusion that the annual reports of our Secretary and Treasurer, which you have just heard are, taken in their entirety, altogether satisfactory. It becomes my pleasant duty to dwell more particularly on some special features of these reports and to congratulate you on the splendid work which has been accomplished by the Society during the past year, and on the excellent financial showing made.

It is true that in point of membership we are not quite so strong as we were at the close of the year 1908, and that during the year 1909 our accessions to membership were not so many as they were for the previous year. The decrease which has manifested itself is, however, more theoretical than actual, for the real strength of any society is shown in the life and activity of its members and those who, after election, do not qualify or who have become chronically delinquent, become a source of weakness rather than of strength to the organization. For this reason the Executive Committee has felt obligated, after mature consideration, to drop 34 delinquents from our membership list.

Recognizing the fundamental necessity of vitality, it has been the endeavor of the Executive Committee to augment our membership, but in doing this special regard has been had to receiving nominations which not only assured the fitness of the candidate but also the certainty of his qualification in case of election; and so it has eventuated that in our new accessions not only have we secured most excellent additions, but there has not been in a single case a failure to qualify. Such
a condition surely augurs well for our growing strength and the stability of our organization.

Your Executive Committee has been most assiduous in the execution of its duties. Early in the year it became apparent that the Society's interests would be best served if the meetings of the Executive Committee were held not half an hour previous to the regular monthly meeting of the Society, but on an evening a week previous thereto. The result of this change proved fortuitous, for the Executive Committee was thereby enabled to consider without haste all the needs of the Society and to discuss in deliberate and thoughtful fashion those measures which would tend to further promote its continued success. The meetings of the Executive Committee were uniformly marked by undiminished enthusiasm and the keynote of their actions was always sounded in the word "Progress." How successful these endeavors were is evidenced in the series of papers which have been submitted during the past year. I think I am safe in asserting that at no time in the history of the Society have an equal number of papers been read in any one year which have been of greater importance, which have displayed on the part of their authors more painstaking interest and thoroughness in the treatment of the subject selected, and which have commanded from the public interested in scientific work greater attention and appreciation. It is not in a boastful spirit that this statement is made, but rather in one of acknowledgment to the authors that their work has been not alone for the Society, but that it has appealed most forcibly to the general scientific and technical public.

That this should be so is not at all surprising, for not only has the scientific and professional standing of the authors put the stamp of originality and merit on their papers, but the varied range of the subjects treated has demonstrated that this is a scientific Society in the truest sense of the word, that it is one in which the search after truth is not limited to one branch of science, but covers many, and that discus-
sions on subjects of pure science are just as important and essential to our organization as are those of technological interest.

And it is just herein that the wisdom of the founders of this Society becomes more and more apparent. As the years roll by and the realms of pure science become more and more extended, and as the discoveries in the field of pure science are made use of in the creation and development of industrial enterprises, so this Society in drawing to itself all classes of scientific men can and should be made the medium for the spread of knowledge beneficial to every interest which can profit thereby. Our Society is big enough and broad enough to assimilate in its membership scientific men of every professional vocation and so far from there being anything incongruous in such an assemblage, it is, to my mind, the most rational relationship. Whether we have as some members mining engineers who concern themselves with the special characteristics of ore deposition of the mining properties which they may be exploiting or pure geologists who may theorize as to the methods of ore deposition; or whether we have among us the physicists who interpret the complex phenomena of electricity or magnetism and which are taken advantage of to magnetically separate ores into varying products adapted to different metallurgical processes; or whether such members are analytical chemists who investigate the behavior and properties of certain chemical compounds, and whose discoveries the metallurgists may use for the betterment of their smelting processes, or for the recovery of by-products formerly wasted; or whether we have among us meteorologists who devote themselves to the study of nature's forces and find themselves associated with electrical and irrigation engineers who deal with the conservation of those forces and their utility in power and reclamation projects, we must all agree that such association is and must be of highest mutual interest and that it must and does reflect itself in complementary benefits to all.
And so it should be our unremitting endeavor, if the Society is to wax and continue to grow strong, to continually increase in numbers, seeing well to it, however, that such growth is one of highest quality and that a membership in the Society carries with it not alone a lustre to the Society but an honor to the member.

The proper housing of the Society has been the subject of much concern to us all. Various projects have been discussed, many suggestions have been made, but none has seemed to meet our conditions, the limited financial means at our disposal not permitting the carrying out of the best suggested project of all by former president Wilkinson, namely, the erection of a building of our own. Happily, however, the last legislature made an appropriation for the erection of a splendid structure for museum and other state society purposes, and in this building, I am pleased to announce, the Commissioners have allotted to our Society the uppermost floor, which will give us 100 feet square to arrange as best suits us for disposition of our collections, our library and our assembly room.

It may take another year or so before this building is completed, but when it is finished we will, I am sure, have every reason to be satisfied and our anxieties in respect to an suitable location will be over.

Denver is a natural center for the assemblage of professional men who act as consulting engineers in their various professions. The growth of our State University, School of Mines, and institutions of higher learning, should bring here men of highest scientific attainments. The development of the industrial resources of our great state is creating new technological enterprises which, if they are to be most successful, must be guided by men of high technical training.

Let it be our fixed purpose to draw all such men to us, to the end that in its membership this Society may reflect not only the true scientific spirit of Colorado, but that of the west, for which Colorado stands, as well.