OREGON STATE COLLEGE

Warm Springs Research Project

Final Report

VOLUME IV: WATER RESOURCES

Part 1. *Report and Recommendations*

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WARM SPRINGS RESEARCH PROJECT

VOLUME IV: WATER RESOURCES

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Part 1: Report and Recommendations

This volume is part of the final report of a study made by Oregon State College for the Confederated Tribes of the Warm Springs Reservation of Oregon. The remainder of the report is contained in the following: Volume I: Introduction and Survey of Human Resources; Volume II: Education; Volume III: The Agricultural Economy; Volume IV: Water Resources, Part 2: Appendices and Bibliography; Volume V: Physical Resources.

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WATER RESOURCES OF THE WARM SPRINGS INDIAN RESERVATION.

By
Elmon E. Yoder

CHAPTER I

INTRODUCTION

The lands of the reservation are extremely variable in topography, geology, and climatology. The western edge of the reservation is formed by the Cascades, a range of rugged permeable lavas having an annual precipitation exceeding sixty to eighty inches. The lands to the east are the broad plateaus, deeply cut by stream erosion, often deeply underlain with impermeable materials, and having an annual precipitation of ten to twelve inches. Snow melt and ground water recharge at the high elevations contribute to the sustained discharge of the streams flowing across the reservation. Ground water is difficult to obtain in moderate quantities at the eastern plateaus, due to the combined adverse effect of low annual recharge rate, deeply eroded terrain, and impermeable deep formations.

Section 1-1: Synopsis.

1-1.1 Contents of Report. This report is a discussion of the water resources of the Warm Springs Indian Reservation. Waters from both ground and surface sources, from wells, springs, perennial streams, and non-perennial streams, are considered. The duty of water from these sources for domestic, stock, irrigation, industrial, and hydro-electric purposes is considered.

1-1.2 Ground Water. The topography and geology of the reservation favors the formation of springs at the lower elevation. This is apparent by the numerous springs which issue at the edge of the valley floors or near the toe of canyon walls throughout the reservation. The springs which issue at higher elevations, often have less discharge and display a tendency for intermittent flow. However, because of their location remote from other sources of water, these weaker springs often have greater value than do the stronger springs which lie below. Wells drilled on the plateau lands must generally penetrate into the strata from which springs emerge at lower elevations. These formations are usually so dense and impermeable that well performance is not substantially greater than from existing springs.

1-1.3 Surface Water. Streams of the reservation flow in a general easterly direction, to be tributary to either the Metolius or the Deschutes River. The headwaters of these major streams, the Warm Springs River, Whitewater River, Shitike Creek, and Mill Creek are found in the Cascade Range. The upper reaches of the streams tend to flow on steep gradients in relatively shallow stream beds. The lower portions of the streams flow on relatively flat gradients, in deeply eroded stream beds. These surface waters contain no dissolved salts or other detrital materials in sufficient quantities to be detrimental.

1-1.4 Duty of Water. Sources of ground water, from either springs or wells, are generally of such small discharge that their use for domestic consumption, stock, or irrigation of small garden plots is limited. Although a serious pollution problem exists at the reservation where domestic water is obtained from shallow wells, poorly developed springs, or surface sources, the correction of the sanitation deficiency does not pose a difficult engineering problem. Irrigation is essential on the reservation to provide satisfactory farming. Adequate water for irrigation is available. For most irrigable lands on the reservation, sufficient water is available from the perennial streams. However, the cost of conveying the water the required distances over rough and difficult terrain to serve relatively small and isolated independent irrigation units is sometimes excessive and beyond the ability for economic repayment. A considerable potential exists for hydro-electric development of the streams bounding and within the reservation. A coordinated plan for the combined power and irrigation development of the streams within the reservation would be desirable for maximum utilization of the potential from the surface waters.

Section 1-2: Objectives.

1-2.1 Purpose. The intent of this report is to provide to the residents of the reservation direction for improved utilization and conservation of present water resources, and for effective planning for the future development of these resources. The report is an inventory of existing developments, and an evaluation of potential resource. A complete evaluation of potential development of a water resource requires a detailed knowledge of method for its intended use. Time allotted for this investigation has not permitted a detailed analysis or design. In this respect the conclusions are more general than specific and the report is one more of investigation and overall direction, rather than one prescribing recommendations in great detail.

1-2.2 Immediate Objective. The immediate objective of the report is to prescribe corrective action for utilization and conservation of present water resource developments. These are such problems as pollution of existing domestic water supplies, the immediate construction of wells or development of springs to correct existing deficient supplies, and the improvement of existing irrigation facilities and their operation. These are problems that are of immediate concern to the residents of the reservation.

1-2.3 Long Range Objective. Water is not abundant at the majority of the reservation lands. For maximum development of other resources, the use of the available supply of ground and surface water should be carefully planned. Such problems for a long range program of water resource development are those of extensive ground water development by wells and springs, coordinated use of surface waters for irrigation and hydro-electric development, and extensive programs for surface water distribution and treatment for domestic consumption. It was the purpose of this report to assess the potential of these more extensive programs of development, and outline the requirements for their construction.

Section 1-3: Organization of Report.

1-3.1 Report Content. The main body of the report is divided into six parts. These are:

Part 1 An introduction describing the content, objectives, and method of preparation.
Chapter I Introduction.

Part 2 A discussion of the principles governing ground water movement and occurrence, and their effect upon springs and wells.

Chapter II Hydrology of Ground Water.
Chapter III Hydrology of Springs.
Chapter IV Hydrology of Wells.

Part 3 A compilation and discussion of existing data pertaining to climatology, surface runoff, and geology of the reservation.

Chapter V Climatology of the Reservation.
Chapter VI Surface Runoff of Streams Bounding and within the Reservation.
Chapter VII Geological Factors Influencing Occurrence of Water within the Reservation.

Part 4 A discussion of the occurrence and use of ground water on the reservation as found in existing and proposed development of springs and wells.

Chapter VIII Springs on the Reservation.
Chapter IX Wells on the Reservation.

Part 5 A discussion of existing and proposed surface water development on the reservation.

Chapter X Domestic and Stock use of Surface waters from Perennial and Non-Perennial Streams of the Reservation.
Chapter XI Irrigation on the Reservation.
Chapter XII Hydro-Electric Development.

Part 6 A bibliography of all sources of information used in the preparation of the report.

1-3.2 Chapter Content. Each chapter of the report is prefaced by a brief synopsis or introductory statement. Each chapter is divided into sections, classified according to a particular aspect of the main chapter topic. All sections are indexed by two sets of numerals indicating chapter and section numbers. Each section is further subdivided into paragraph sub-titles. The paragraphs are indexed by three sets of numerals. This method of indexing has been used throughout the report to facilitate convenient cross-referencing where a particular aspect of water resource is discussed at more than one place. With the exception of the first four chapters, a summary and recommendation section is included at the end of the chapter.

Section 1-4: Method of Investigation.

1-4.1 Source of Data. The preparation of this report has been based primarily upon an analysis of existing data, investigations, and surveys. The entire preparation of this report occurred within an intermittent period between June 1959 to September 1960, a total full time period of approximately twenty weeks duration. Of necessity, little new information could be obtained. The small amount of new information obtained during this interval was of a reconnaissance nature only, not satisfactory for a detailed analysis of an engineering problem. An example is the spring inventory submitted in Appendix XIII-A. The performance of each spring was determined by a single observation during the summer of 1959 in the presence of residents of the reservation familiar with the area. Such casual observations are not satisfactory for a detailed analysis of utilization of these waters.

1-4.2 The greatest source of data resulting from previous investigations was from unpublished and published reports of the United States Geological Survey. The Ground Water Branch, Portland, has conducted some investigations on the reservation that have not at this date been released for publication. These unpublished reports are available in their open office files, and are submitted in full text in the appendices of this report. Acknowledgement is made to the personnel of the United States Geological Survey, Portland Branch, and to the personnel of the State of Oregon Water Resources Board, Salem, for their cooperation during the preparation of this report.

1-4.3 Office records and unpublished reports from the files of the Bureau of Indian Affairs were used when available. It is known that the results from some investigations and surveys conducted by the Bureau were not available. Two known sources of information that were not accessible during the preparation of this report are the irrigation and hydro-electric report of 1912 by W.M. Hincks, and the irrigation survey of 1954 by Burch. The Hincks report is said to be in the Department of Interior record storage at Seattle. Efforts to obtain a copy of the report were unsuccessful. The survey by Burch is still in the form of plane table sheets and transit notes. This information, never processed to a complete report, is said to be in the files of the Bureau of Indian Affairs, Irrigation Division, Portland.

1-4.4 The extent of other existing survey, investigation, reports, or records prepared by or in the possession of the Bureau of Indian Affairs but not available during the preparation of this report is not known. There appeared to be little, if any, effective cataloging of engineering data obtained in previous years. The random and prolonged uncovering of information from this source during the entire preparation of the report took on an aspect of much uncertainty.

1-4.5 Adequacy of Data. Published and unpublished materials pertaining directly to the water resource situation of the reservation are very scarce. More comprehensive and detailed publications are directed toward areas in the Deschutes Basin lying adjacent to the reservation. A program of stream runoff measurements began during the early 1900's has been suspended. Basic information regarding the geology and hydrology of the reservation is very meager. As a result, reports that have been prepared describing development of either ground water or surface water on the reservation have been of a preliminary or reconnaissance nature only. It is regretted that this report, too, must fall in the same category; however, this report is the first known attempt to assemble all previous works, and arrive at conclusions based upon an analysis of the entire water resource potential of the reservation.

1-4.6 Extension of Data. The study of the water resources of the Warm Springs Indian Reservation is not ended by the completion of this report. Much information remains yet to be obtained before a detailed plan for development at the reservation is possible. Nor should the search for this information ever cease, for optimum use of these resources will require continuing compilation and analysis of data and performance records. It is hoped that this report effectively stresses the need for correction of these deficiencies, and that the analysis of available information submitted in this report will be of assistance to further study.

CHAPTER II

HYDROLOGY OF GROUND WATER

Ground water is all interstitial water below the water-table. In general, only a superficial portion of ground water has been studied and exploited. The water holding capacity of a rock depends upon its porosity. Its freedom of movement in a rock is controlled by the size and continuity of the interstitial openings.

Section 2-1: History of Investigations.

2-1.1 Existing Ground Water Data. For both surface and ground water, data on past, present and future requirements are inadequate. McGuinness (31,p.81), in describing the ground water situation in the United States, reports that at a time when use of water is increasing rapidly throughout the United States and is approaching the feasible limits of development in many areas, we must admit that we know little of how much we use, or how much water we have available. Generally, available data on surface water are more extensive than are that of ground water.

2-1.2 Probably less than 5% of the country is covered by detailed ground water studies permitting reasonably accurate planning. For areas lacking detailed ground water investigations, the only additional source of data for predicting the occurrence of ground water is from the records of the geology and climate of the region.

2-1.3 Work of the U. S. Geological Survey. Bennison's conclusion (5, p.472) is that there are very few people in this country, and only one agency of the government, capable of making a thorough ground water inventory. This agency is the United States Geological Survey. Ground water surveys made by individuals or by drillers are not surveys in the full sense of the word, but are simply field investigations.

2-1.4 As of 1951 there had been nearly 2000 reports and papers on ground water published by the Geological Survey and other cooperating agencies. Papers published through January 1946 are listed in Water-Supply Paper No. 992. Several hundred have been published since. There are also several hundred unpublished reports in open files of the Geological Survey.

Section 2-2: Classification of Sub-Surface Water.

2-2.1 Interstitial and Internal Water. The two major types of sub-surface water as classified according to their origin and occurrence are interstitial and internal. Interstitial water is water that fills pores or openings of a soil or rock formation. The interstitial water is further divided as to its origin, being either external interstitial or internal interstitial. External interstitial water is derived from atmospheric or surface sources, and is of most immediate interest. Interstitial water of internal origin (sometimes called juvenile water) and internal water (sometimes referred to as primative and resurgent water) are of secondary interest as a source of available ground water.

2-2.2 External Interstitial Water. The external interstitial waters occur in two zones separated by the water-table surface. Both movement and occurrence of water in these two zones are different. Water above the water-table is referred to as suspended water, and is found in the zone of aeration (sometimes called the unsaturated zone). Water below the water-table is called ground water (sometimes referred to as phreatic water) and is found in the zone of saturation.

2-2.3 Zone of Aeration. Suspended water in the zone of aeration is of three main types, classified by their location. The first, soil water, is the water limited to the soil mantle and is reached by plant roots. The second, capillary water, occurs only in the capillary fringe adjacent to the water-table, and is at the bottom of the zone of aeration. A third type of water lies between the soil and capillary water, and consists of three varieties, being gravity, pellicular and perched water. Gravity water, sometimes called vadose water, moves downward through the zone of aeration. Pellicular water adheres to the rock and soil surface due to molecular attraction, is not moved by gravity, but may be abstracted by evaporation or transpiration.

2-2.4 Perched Water. Perched water occurs locally in the zone of aeration, impounded above an impermeable barrier. The upper surface of a perched body of water is a perched water-table, and should not be mistaken for the main water-table. Perched water may form an important source of sub-surface water if the confining barrier is extensive and has suitable conformity. As a rule, wells tapping perched waters are undependable, often having small yields and inclined to go dry during prolonged dry spells.

2-2.5 Zone of Saturation. Ground water occurs in the saturated zone. It is of four types. The first two are of most immediate interest. The first, free water, occurs below the water-table and is bounded on the bottom by the first effective confining stratum. The second, confined water, occurs between two confining strata. The third and fourth types are the fixed ground water found in sub-capillary openings not moved by gravity, and connate water entrapped in the rocks at the time of their formation. Fixed ground water in the zone of saturation is to be distinguished from the pellicular water which occurs only in the zone of aeration.

2-2.6 Classification by Texture and Structure of Aquifer. Tolman (60, p.266) classifies the free and confined water in the saturated zone according to the type of aquifer in which they occur.

I. Ground water in permeable granular material.

II. Ground water in consolidated rocks of small permeability and usually of small porosity.

III. Fissure water, and cavern water.

Section 2-3: Duty of Water.

2-3.1 Domestic Use. Domestic use is the highest use to which water can be put. Water is absolutely necessary for the maintenance of human life. Although domestic water has the highest priority, the prospective use for such purpose is often small in comparison with the total amount used for irrigation. The normal range of use of piped water in dwellings is from twenty to eighty gallons per capita per day, the average being about fifty.

2-3.2 Irrigation and Stock. Water used for the growth of human food is the next highest use for water. Water used for livestock and for irrigation of food crops is of this type. Daily drinking requirement of dairy cows is about twenty gallons, with an additional twenty gallons required for cleaning. A horse or a steer require about fifteen gallons daily. Hogs and sheep require approximately four and two gallons daily, respectively. To produce ordinary agricultural crops in an arid region, the meager rainfall must be supplemented by water from wells or that diverted from streams. Gardens may need as much as forty gallons per day per thousand square feet of area.

2-3.3 Industry. The use of water for industry is of less immediate importance than for either of the fore-mentioned needs. Bennison (5,p.468) reports that where ground water is available, industry invariably prefers it to other sources of supply. Uniformity of quality, low water temperatures during summer, and often low development costs are reasons given for this preference.

2-3.4 Re-use of Water. Use of water by one demand does not necessarily preclude the use of the same water by another demand. Waste water return and deep percolation from irrigation as great as 50% of total amount diverted is frequently encountered. This water is available for recharging of the ground water supply. Industrial waste water, if released at a required quality, is available for direct re-use, or becomes available for ground water recharge.

Section 2-4: Quality of Ground Water.

2-4.1 Stability of Quality. The quality of ground water tends to remain uniform, having little if any seasonal qualitative fluctuations. Both chemical composition and temperature remain nearly constant throughout the year. The deeper ground waters usually show greater stability in their quality.

2-4.2 Temperature. The temperature of earth materials below the surface is not subject to as great a range of temperature as air or surface waters. Because ground waters are in intimate contact with the earth materials for a prolonged time, they also remain at a relatively uniform temperature. Deeper ground waters show greater temperature stability than do the shallower ground waters. There is also a considerable increase in temperature from the surface downward. This amounts to about one degree Fahrenheit for each fifty to one hundred feet of depth.

2-4.3 Mineralization. Ground waters tend to be more highly mineralized than do surface waters. From the moment that water reaches the ground as rain or snow melt and then begins to flow over the surface of the ground to seep downward to the water-table, or to percolate through the rock material in the zone of saturation, it begins to enter into chemical combination with the rock materials. Surface waters usually are not in as close contact with the soil and rock materials as are the ground waters, nor is the length of time in which they are in contact as great. These factors contribute to the greater mineral content of the ground waters.

2-4.4 Mineral content of ground waters tends to be uniform throughout the seasons and years. Surface waters, though generally less mineralized, may fluctuate widely in quality. Their make-up may vary from the nearly pure rain water or snow melt in flood times to essentially nothing but ground water during periods of minimum flow. The deep ground waters are usually more highly mineralized than those from lesser depths. The character of the mineral content of ground waters depends largely upon the chemical character of the strata through which they flow.

2-4.5 Water is made hard primarily by the solution in it of carbonates and sulphates of calcium and magnesium. Calcium, which is the principal constituent causing hardness in water, is supplied from three principal sources: limestone, calcium chloride, and gypsum. The relative hardness expressed in parts per million of dissolved carbonates is indicated:

Relative Hardness	Parts per Million, Carbonate
Very soft	0 to 30
Soft	30 to 50
Moderately soft	50 to 100
Moderately hard	100 to 120
Hard	120 to 150
Very hard	150 to 240
Excessively hard	Over 240

Section 2-5: Pollution of Ground Water.

2-5.1 General Condition of Water. McGuinness (31, p.37) reports that due to the extent to which water is filtered in passing through the soil and rocks, nearly all ground water is of good sanitary or bacteriological quality. An exception to the general purity of ground waters is the shallow and poorly constructed wells located too near sources of contamination, such as privies or barnyards. Surface water is safe to drink without treatment only when it is derived from uncontaminated watersheds.

2-5.2 Travel of Polluting Agents. Polluted sub-surface water can travel vertically and horizontally considerable distances, if the underground strata are very permeable or contain natural channels. Soil and mantle deposits have a purifying effect on polluted waters to shallow wells. Nevertheless, waters of many shallow wells are often polluted by seepage from nearby sources. Deep wells can become polluted from sources considerably removed. Pollution can be of a most dangerous character, because its existence is unseen and unrealized. The clear and sparkling polluted waters seldom give apparent evidence of their danger.

2-5.3 Rock Texture. Fuller (14, p.16-16) describes the relative safety from pollution due to different earth materials. The safety of ground waters used for domestic purposes when obtained near any source of pollution depends principally upon the character of openings through which the ground waters pass. This in turn depends on the type of materials in which the waters occur or through which they have flowed. Those earth materials having small interstitial openings retard the velocity of ground water, and are in close contact with the water. The filtering action of such materials is good.

2-5.4 Clay and Shale. Ground waters from clay and shale are usually free from pollution. Because of the filtration of the waters through the exceedingly small interstitial openings, slowness with which any polluting matter can progress, the slight distance the polluting matter reaches in such material, ground waters from clays and shales are usually of good bacteriological quality. Ground water issuing from clays and shales is often quite highly mineralized.

2-5.5 Sand and Gravel. In general, ground waters from fine sands and gravels, if taken from a considerable distance below the surface, are free from pollution. In passing downward through sand the surface waters are subjected to natural filtration, expecially in the finer sands. During seepage and percolation through the finer sands, the substances causing pollution are frequently removed, at least in part. In the coarser sands and in the more closely graded gravels, water velocities are more rapid. Here conditions are less favorable for filtration, and the water may remain polluted for great distances.

2-5.6 Till. The ground waters from till generally are uncontaminated because of the natural filtration from the clay and sand of which till is largely composed. If, however, underground flow has caused the formation of more or less definite tubular channels through the material, and if such a channel leads from a source of pollution, the water is unsafe to drink when untreated. Once polluted, it may remain so for long distances, as the underground channel offers no natural filtration. Fuller (14, p.17) recommends that ground waters from till, or the coarser sand and gravel formations be tested if there appears any likelihood of pollution.

2-5.7 Fractures. Ground waters from fractured rocks generally occur in complex networks of intersecting passages. It is possible for polluted water to pass in a zig-zag course for great distances without being subjected to any natural filtration. Ground waters from broken and jointed igneous rocks in thickly populated regions are inclined to be polluted, and should be tested for purity if used for domestic purposes.

Section 2-6: Occurrence of Ground Water.

2-6.1 Rock Porosity. The capacity of a rock to store water depends upon its porosity. Effective porosity is governed by the following:

I. Shape and arrangement of constituent particles.

II. Degree of assortment of particles.

III. Cementation and compaction.

IV. Removal of mineral matter through solution.

V. Fracturing of rock resulting in joints and fissures.

VI. Inter-connecting openings formed by gas pockets or flow tunnels.

2-6.2 Permeability. Size and continuity of the interstitial openings control the permeability of the material. This is its capacity to transmit water. Although increased porosity of a water-bearing material increases its ability to store water, this factor alone will not determine its ability to yield ground water in usable quantities.

2-6.3 The fine-grained materials, such as clay, have a relatively high porosity, and consequently have the ability to store large amounts of water. However, because of the extremely small size of interstitial openings in clay, it cannot normally release stored water in usable rates. It is referred to as being impermeable. Fine-grained rocks yield little, if any, water; such water that is released comes from joints, faults or folded planes.

2-6.4 Sand and gravel aggregates may have a low porosity due to a wide size assortment of the constituent particles. But, because of their larger effective interstitial openings and small specific retention, they have the ability to absorb and release ground water at favorable rates.

2-6.5 Other Factors. McGuinness (31, p.8) reports the capacity of a rock material to absorb, store and yield water depends upon the abundance, size and shape of openings in the rock. However, he describes other factors that also determine the occurrence of water in a rock formation. The position of rocks with respect to the land surfaces, the way they dip or are faulted, the way in which they alternate with non-water bearing rocks, their structure, and the extent to which they are exposed and available to recharge also determine the occurrence of water. All but the tightest rocks, clay, soft shale, volcanic ash, or dense unfractured hard rocks will yield at least a little water in usable quantities where the favorable conditions mentioned exist.

2-6.6 Rock Origin. Rock may be geologically classified according to its origin. That is, its origin may be either igneous, metamorphic, or sedimentary. Igneous rocks result from the action of heat within the earth, usually accompanied by fusion, and are formed by solidification of molten magma. Metamorphic rocks are a result of a pronounced physical transformation from other rocks, being effected by pressure, heat or water. Metamorphism usually results in the forming of a more compact and crystalline rock. Sedimentary rocks are those that originate from depositions of sediment, from precipitation from solution, or from calcareous remains of organisms. Better water yielding formations are usually associated with the coarse and closely graded sedimentary deposits.

2-6.7 Rock Structure. Rock aquifers may be classified according to the distribution of openings within the rock material, a classification of most significance in a study of ground water.

I. Uniform distribution.

  A. Consolidated granular.
  B. Unconsolidated granular.

II. Non-uniform distribution.

  A. Dense.
  B. Fractures and solution openings.

2-6.8 Formations of Uniform Distribution. The coarse and unconsolidated granular formations where found below the water-table are good water producers. If such a formation contains a wide assortment of particle sizes, the size of the predominantly smallest grains determines the effective permeability, which in turn determines the ability of the formation to yield water at usable rates. The consolidated granular formations are not reliable sources of water, having neither favorable porosity nor adequate permeability.

2-6.9 Formations of Non-Uniform Distribution. Considerable water penetrates along the fissures and cracks of some of the non-uniform rocks, but such water is often released slowly. It is along these joints, and the unconformity between adjacent formations that the largest supplies from the dense and non-uniform rocks are obtained. Fuller (14, p.15) reports that these joints are most common near the surface and diminish in number and definiteness as depth increases. For this reason, water supplies from most dense rocks occur within 500 feet of the ground surface.

2-6.10 The water in fractured material varies from the large and extensively connected bodies extending over wide areas and subject to considerable volume and flow, to the minute filaments of water incapable of little discharge. Their occurrence and motion are controlled chiefly by the size, shape, extent and continuity of the openings. Usable water is usually in openings of super-capillary size, and not subject to any appreciable film forces. Large flows that are encountered in occasional fractures and channels are usually short lived unless the aquifers are directly connected with surface water or with other formations functioning as sub-surface reservoirs.

2-6.11 Depth of Ground Water. Ground water usually saturates the strata to a depth where the materials are so consolidated due to the overhead weight that cracks, fissures and interstitial openings are eliminated. Mead (32, p.393) reports this depth to be about 6,000 to 10,000 feet, but that, practically, ground water is confined to the upper 5,000 feet in sedimentary rocks and to about 500 feet in the crystalline rocks.

2-6.12 Climate. In the arid west, the mountains act as catchment areas for precipitation and as sources of water for the adjacent desert valleys. Only exceptional precipitation on the valley floor is capable of producing direct ground water recharge. In the average year, direct recharge during the summer months is very small if not negligible. In an outline for estimating ground water supplies, Meinzer (38, P.111) suggests that in the summer when vegetation makes heavy demands on the soil moisture, most rainstorms do not contribute to ground water supply, nor do they effect the water level in wells.

2-6.13 Tabular Summary. See Table II-A for tabular summary of characteristics of rocks and their ability to yield ground water.

Section 2-7: The Water-Table.

2-7.1 Definition. The water-table is the boundary between the zone of aeration and zone of saturation. It is the upper surface of the body of free water which completely fills all openings in materials sufficiently permeable to permit water movement. McGuinness (31, p.54) simplifies a description of the water-table, describing it as being similar to a free water surface at atmospheric pressure. The ground water behaves like water in a surface reservoir, except that friction makes it move more slowly. Although the surface of the water-table is subjected essentially to atmospheric pressure, it has many surface irregularities and is continually fluctuating up and down.

2-7.2 Capillary Fringe. In the granular materials the water-table is not a distinct water surface. The material just above the saturated zone is saturated with capillary water, the capillarity extending upward further in the finer materials. In such formations the water-table is located by the point at which water will stand in a test hole or well penetrating into free ground water. That point is always below the upper limit of the capillary water. In granular formations made up of the larger particles, film forces decrease or become practically non-existent; the water-table surface then does approximate the character of a distinct water surface. The water-table in a fissured rock formation having interstitial openings of a super-capillary size is a distinct but discontinuous water surface. Its surface is an infinitesimal number of small and individual surfaces constituting a small part of a given area.

2-7.3 Film Forces. The water-table separates two regions where the forces acting and the resulting motions of sub-surface water are different. Above the water-table the interaction of film forces and gravity produce the complex motions of seepage and capillarity. Tolman (60, p.226) reports that below the water-table the ground water is not subjected appreciably to forces other than those attributed to gravity, except locally where forces due to heat may be encountered.

2-7.4 Effect of Varying Permeability. The effect of varying permeability of formations along the water-table profile is to cause a water-table having a variable slope. Assuming continuous flow, the coarser formations will display a more level water-table slope, while the more impermeable formations tend to steepen the water-table slope. Should an impermeable, or nearly impermeable barrier outcrop, it could act as a dam to the underground flow. Effluent seepage could occur at the upper contact of the impermeable formation if underground flow was sufficiently restricted. If the differential in permeability is not so pronounced as to actually give rise to effluent seepage, one may expect closely spaced water-table contours in the less permeable formations and more widely spaced contours in the formations having greater permeability.

2-7.5 When thin permeable surface deposits overly impermeable formations, the slope of the lower formation is important in determining the water-table slope. Capacity of the thin surface deposit to carry water is proportional to its cross section and velocity of water movement. Assuming constant thickness of the top deposit, if the slope of the basement formation decreases the water-table will appear at shallower depths.

2-7.6 Relation to Topography. The water-table usually follows in a general way the topography of the country. It is found deeper under the high places and closer to the ground surface at the lower elevations. Tolman (60, p.27) describes the water-table as a subdued replica of the surface topography. Where the water-table occurs in an extensive interconnected deep fractured formation the water-table is usually less dependent upon topographic variation. A deeply dissected topography usually has a water-table far below the surface of the plateaus. A flat area without a low point of ground water discharge is usually associated with a water-table close to the surface.

2-7.7 Water-Table Maps. Water-table maps are contour maps of the water-table surface. They are useful for studies of water-table elevation, ground water movement, ground water recharge and withdrawal, and permeability of sub-surface formations. These maps are constructed from measurements of water levels in test holes, from static levels in producing wells, or from upper contacts of effluent seepage.

2-7.8 Effluent and Influent Seepage. The water-table outcrop determines the surface areas subject to either influent or effluent seepage. Influent seepage is seepage which tends to recharge the ground water supply, while effluent seepage discharges water from the ground water formation. Influent seepage occurs where the water-table is below the ground surface. Effluent seepage starts at the upper outcrop point of the water-table with the ground surface and continues throughout the area lying downslope where the water-table is at the surface. In an area cut by a stream the water-table may outcrop where the stream intersects the water-table. At that point the stream changes from influent to effluent, or from a "losing" stream to a "gaining" stream.

2-7.9 Ground Water Trench. The water-table on either side of a river usually slopes toward the river. Bennison (5, p.23) reports that very few bodies of ground water are supported or maintained by rivers. Mead (32, p.393) describes water levels of streams as being generally dependent upon the effluent movements from the ground water reservoir. Except in relatively rare situations, rivers and other perennial water bodies are supported by effluent discharge. The depression of the water-table by a stream, gully or other drainage produces what is termed a ground water trench.

2-7.10 Ground Water Mound. Where a stream or lake contributes to the ground water supply through influent seepage, the underlying materials become more or less saturated and form a rise in the water-table. Such a rise is called a ground water mound or a ground water ridge. These are of two types, classified according to whether or not the mound contacts the overlying surface water. Factors favorable for the non-contacting mounds are deep depth to regional water-table, underlying beds of uniform and high permeability, a vertical downward decrease in permeability, and presence of a less permeable formation between the surface water and water-table which results in a perched and spread body of sub-surface water. Underlying formations such as well sorted sand having little difference of permeability in vertical and horizontal directions may supply water faster vertically than it can spread it laterally. The resulting water-table mound is built up to the source of the influent seepage and makes contact with the surface water.

2-7.11 Water-Table Fluctuations. The water-table is not a static surface, but is subject to continual fluctuations. It is almost nowhere a level surface. Irregular movement at any given locality is not only due to additions and withdrawals from the ground water at that point, but is also the response to effluent and influent seepage over its entire surface. These changes occur slowly. Water-table adjustments are more rapid in formations having high permeability.

2-7.12 The movement of the water-table over the seasons and years is one of the surest indications of the extent of ground water withdrawal and replenishment. Although the measurement of the static water level in wells offers readily available information on location and fluctuations of the water-table, Bennison (5, p.60) describes the general failure of even the large users of ground water to take advantage of this opportunity. Many times the only measurements taken of the water-table are those made at the time the well is drilled. Years later, when it is feared that the water supply is failing, it is found too late the water-table has dropped. This situation could be anticipated by taking regular measurements, and preventive action taken.

Section 2-8: Movement of Sub-Surface Water.

2-8.1 Zone of Aeration. Forces causing movement of water in the zone of aeration are gravity, unbalanced film forces, transpiration and evaporation, and chemical forces. The movement is in a general vertical direction. Turbulent flow may exist above the water-table in the large interstitial openings or fractures. Except as they may affect cropping and irrigation practices, and ground water recharge, the movements of water in the unsaturated zone are of secondary importance.

2-8.2 Zone of Saturation. Below the water-table ground water always flows under the influence of gravity, from points of higher potential to points of lower potential. Flow takes the most direct possible path producing the steepest potential gradient and maximum rate of flow. Ground water movement is always in the maximum downslope direction of the water-table slope.

2-8.3 Relation of Water-Table Slope, Velocity and Permeability. A basic law of ground water flow is that water-table slope varies directly as velocity and inversely as permeability. Although turbulent flow is possible in the saturated zone if a free entrance and exit occur, usually water movement in the granular formations is the laminar flow of percolation.

2-8.4 Water movement in a granular formation is more predictable than is the irregular and complex flow of a fissured material. Average effective velocities have been tabulated in unconsolidated materials for one percent hydraulic gradient as varying from only 0.001 to 0.004 feet per day for black gumbo or clay to as much as 25 to 30 feet per day for gravel.

2-8.5 In the granular formations, the size of the finest grains which occur in sufficient quantity to effectively surround the coarser material controls the velocity of percolation. The closely graded formations containing large particles have essentially the same porosity as do the closely graded formations containing small particles. From the advantages of greater yield, the former is preferred as an aquifer. Heterogeneity resulting from addition of smaller ingredients reduces both capacity and discharge due to reduction of porosity, permeability, and specific yield.

Section 2-9: Occurrence of Ground Water in Different Types of Rocks.

2-9.1 Dense Igneous Rock. The structural make-up of igneous rocks depends upon the amount of heat, rate of cooling and depth below the surface when heating and cooling took place. As a result of this heating and cooling, many crystalline arrangements are found. This wide range of internal structure controls the amount of water they can hold. The hard, glassy, crystalline types of igneous rocks are not regarded as good water producers except in unusual cases. Bennison (5, p.25) reports that outside of lava deposits, igneous rocks are not a dependable source of water.

2-9.2 Lava. The material of lava in general is impermeable. Effective porosity occurs chiefly in basaltic lava. The rhyolitic and andesitic lavas usually are of little importance as an aquifer, being dense and unfractured. Permeable volcanic formations composed of pyroclastics and zones of intense fracturing are often found in and adjacent to volcanic centers. The inter-bedded ash, lava and gravel may form permeable formations capable of yielding ground water.

2-9.3 Basaltic Lava. Baker and Conkling (3, p.300) regard basalt as one of the best water-bearing materials of the dense rocks. This lava when molten is free-flowing, susceptible to development of gas pockets, flow tunnels, and other irregularities. The material is likely to be effectively permeable as the cavities and fractures are usually formed by stresses developed during cooling. Basalt, being very fluid when molten, is usually deposited in thin successive flows. The highly fractured flows are caused by stresses due to differential cooling of the upper and lower surfaces of the flow. The fractures are at right angles to the direction of flow. Later movements cause successive cracks and fissures to develop at right angles to the layering. The vast network of cracks in such thin basaltic flows produce a huge underground reservoir if located below the regional water-table.

2-9.4 Rhyolitic Lava. Openings in rhyolite due to gas expansion may be developed, but these gas pockets, if present, are usually not interconnected. Rhyolite in the molten condition is viscous, and as a result most of the rhyolitic lava flows are of considerable thickness. Joints and fractures due to any differential cooling between the upper and lower surfaces of the flow are small, and penetrate but a short distance into the formation. The result is a dense and impermeable material, usually incapable of yielding water in useful quantities.

2-9.5 Ash. Wind blown volcanic ash forms tuffs that are porous, but if consolidated are so fine-grained in texture as to be practically impermeable. Baker and Conkling (3, p.300) report that volcanic sediments deposited as fragmental material may or may not be of such a character to yield water in useful quantities. Any permeable beds in water-laid tuffs are often localized, lens shaped, and cross-bedded. Tolman (60, p.312) describes tuff beds forming a confining barrier for perched water. The conclusion is that volcanic ash serves more as an aquiclude than it does an aquifer. Also see paragraph 4-7.2.

2-9.6 Clay. Because of the high porosity of clay, it contains large quantities of water. However, the interstitial spaces are so minute that water is released slowly, and specific yield is low. Clay is impermeable in the sense that little or none of the water it contains can be utilized as a source of supply. Fuller (14, p.13) describes clay formations close to the surface having sufficient permeability to yield small to moderate amounts of water. The ability of the shallower clay formations to yield water is also described by Tolman (60, p.141), but is attributed to channel flow through root perforations, and not to true interstitial flow.

2-9.7 The greatest importance of clay is probably its action as a confining layer or aquiclude which prevents ground water from escaping, or acting as a barrier collecting water from overlying permeable beds and bringing it to the surface. Usually the clay content of a formation determines its yielding ability. Formations having a predominance of clay are not likely to be a good source of water.

2-9.8 Shale and Slate. The occurrence of water in shale and slate is similiar to that in clay. All are poor water producers. Both shale and slate are less elastic than is clay, hence are subject to greater fissuring and cracking. Shale may yield moderate to large quantities of water, depending upon how much the upper portion of the formation is fissured and broken. Slate may provide some water from the crevices along bedding and cleavage planes. The most important use for formations of shale and slate is their action as confining barriers.

2-9.9 Till. Because of the heterogeneous nature of till, its ability to yield water varies. It is a mixture of clay, sand, gravel, and boulders. Its porosity and permeability depend on size gradation and arrangement, and upon the predominance of clay. Bennison (5, p.29) describes till as a mixed formation having low porosity, hardly capable of large producing wells. Fuller (14, p.29) describes till as being usually not bedded, and containing water in more or less definite tubular channels. The tendency for channeling is reported to cause wells drilled in till to vary widely in their success.

2-9.10 Sand and Gravel. Sand, gravel and sandstone formation are capable of yielding large amounts of water. Depending upon the degree of assortment of particle size and shape, porosity and permeability are usually high and specific retention is small. Porosities range from as low as about 20% for gravels with sand matrix to as high as 45% for the closely graded formations. Waters from such deposits are usually of good quality if reasonable care is taken against pollution. Waters from such sources are often mineralized, having dissolved material from the more soluble particles. The closely graded aggregates are associated with large yields, with optimum discharges anticipated from the coarser formations.

2-9.11 Conglomerates and Breccias. When sand and gravel are cemented into a conglomerate or into a breccia they become so impermeable as to yield little or no water. Cementation is caused by mineral water carried in solution in the ground water. Usually the cementing agents are carbonates of silica, calcium and iron oxide. The cementing action may be accompanied by a mechanical deposition of fine particles carried along by the water in suspension.

2-9.12 Alluvium. The sand and gravel alluvial deposits vary from the finest particles of sand and silt up to boulders mixed with the detrital deposits of stream flow. Sometimes such deposits are found where only the coarser particles remain, the finer having been washed away. If such formations are extensive, large water yields are possible. In alluvial deposits the upper portion is often fine or poorly graded material, gradually changing to larger and closer grading in the lower portions.

Because many alluvial deposits are localized, their ability to produce abundant water yields may be limited even though their texture is ideal.

2-9.13 Limestone. Water occurs in limestone mainly in solution channels and caverns. The water originally probably followed joints or bedded plains which were gradually enlarged by solution. The occurrence of the solution channels is very irregular and their location can seldom be predicted. However, because most deep wells into such formations penetrate one or more of these interconnected passages, yields are usually very good. The waters from limestone are generally hard. Polluting agents can travel great distances in the solution channels.

Section 2-10: Free and Confined Ground Water.

2-10.1 Free Ground Water. Free ground water occurs in the zone of saturation within interconnected interstices, lying above the first impermeable barrier. Its movement, unhampered by overlying confining material, is controlled by the water-table slope. The water moves in the direction of steepest slope of the water-table. It moves as a single body of water, usually using its energy by percolation. Because at all points the water-table is subject to atmospheric pressure, and because percolating waters have negligible energy due to velocity, the energy of free ground water is that of position only. It is impossible for free ground water to rise in a well or a bore hole to a point above the water-table, and in a static situation the water will rise to the surface of the water-table.

2-10.2 Meinzer (36, p.157), in a summary of ground water resources of the United States, reports that the water supplies from both springs and wells are derived chiefly from formations yielding free ground water.

2-10.3 Confined Ground Water. Confined ground water is overlain by a formation sufficiently impermeable to be hydraulically independent from all overlying waters except those at the upper edge of the confining barrier. Confined ground water is found below either free ground water or another stratum of confined water. The water moves in the confined stratum under the pressure due to the difference in potential between intake and discharge area of the confined water. Confined ground water has no water-table.

2-10.4 McGuinness (31, p.12) describes the flow of confined ground water:

> "Under artesian conditions water becomes confined under pressure between two bodies of impermeable rock. The free ground water flows through the zone of saturation with the general slope of the water-table to a point where that zone is interrupted by an impermeable bed. Part of the water may pass above the bed and continue to flow under water-table conditions. Part of it flows beneath the bed. Now it is confined, pressing upward against the impermeable bed with a head equivalent to the difference in elevation between the elevation of the water-table

at point of confining recharge and the elevation of point of discharge, less the loss of head in the resulting friction of movement."

2-10.5 Confined Ground Water Classification. Wells yielding confined ground water may be classified according to their static head. A sub-normal artesian well displays a static level below the water-table. A sub-artesian well has a static level above the water-table, but below the ground surface. A free-flowing artesian well is one which has a static level above the ground surface.

2-10.6 Free Flowing Artesian Conditions. Chamberlain (8, p.131) lists conditions necessary for free-flowing artesian flow:

I. A permeable stratum to permit the entrance and passage of water.

II. Underlying impermeable bed to prevent downward percolation.

III. Overlying impermeable bed to prevent escape of water upward.

IV. Inclination of overlying bed or water table so that the elevation of the water-table at the edge of the overlying bed will be higher than the ground surface at the well. To produce a free-flowing artesian well the hydraulic gradient of the underlying confined ground water must pass above the ground surface at the well.

V. Suitable exposure at upper edge of permeable stratum, so that it may take in a sufficient supply of water.

VI. Adequate rainfall or other source of ground water recharge to furnish a supply.

VII. Absence of any easy escape to the water at a lower level than the surface of the well.

Section 2-11: Ground Water Recharge.

2-11.1 Time of Natural Recharge. In most regions of the United States, recharge of the ground water reservoir occurs chiefly during the late autumn, winter, and spring seasons. Meinzer (38, p.111) attributes this to the duration and intensity of rains during this time, and to the low demands for soil moisture through evaporation or transpiration. In the very cold regions the ground is likely to remain frozen continuously for long periods, delaying recharge until the ground thaws.

2-11.2 The recharge condition described has particular significance in the arid west. Here the mountain ranges receive much more rainfall or snow melt than the adjacent basins and plateaus. Although the mountains are built mainly of dense, impermeable rocks having steep slopes, they often have enough ground water storage capacity to even out and prolong considerably the runoff resulting from rainfall and snow melt. Summer rainfall is usually of short duration, and field capacity is reduced between storms so that the rain water cannot completely replenish soil and pellicular water depleted by evaporation and transpiration. Under these conditions there is no contribution to ground water. Rainfall during summer is an important source of ground water recharge only during prolonged or unusually wet seasons.

2-11.3 Geologic Factors. Other sources of ground water replenishment may be influent seepage from streams, lakes, irrigation ditches or other artificial water bodies. Because of the general tendency for the natural water bodies of surface water to be "gaining" from effluent seepage, sources of recharge other than precipitation may be limited to those of artificial origin. One of the most important of these sources is seepage from irrigation ditches and the fields served. Ground water recharge as great as fifty percent of all diverted irrigated water is frequently reported.

2-11.4 Only water-table aquifers containing free ground water may be recharged directly from above. The confined aquifers must be recharged by movement of water from an area where the upper confining bed is absent. In general, water-table aquifers are those with the greatest recharge rate and yield.

2-11.5 Soil and rock characteristics favoring a high recharge rate are a high effective permeability and flat topography. Debris cones occur at mouths of drainage ways where a sudden decrease in surface water velocity deposits gravel and debris. This type of exposed formation affords an excellent opportunity for recharge.

2-11.6 Influent seepage to the water-table must pass through the zone of aeration. If the water-table is at the ground surface, ground water recharge is impossible. Before water reaches the water-table all pellicular water depleted by evaporation and transpiration must be replaced.

2-11.7 Influent seepage in cracks, fissures and in flocculated clay is more erratic than is seepage through the granular materials such as deflocculated clay, sand, and gravel. Above the water-table fissured rocks are subject to intense drying caused by oxidation. Before seepage is possible, rewetting is necessary. The gravity water then develops water-air films across the narrow fractures, and impedes water movement to the larger openings. The resulting rate of seepage for ground water recharge under these conditions is extremely variable.

2-11.8 Water Spreading. Recharge of the ground water supply by artifically imposed influent seepage has been in practice in the United States for about 75 years. This is sometimes referred to by the term "water spreading," and is applied to any operation where surface water is distributed to permeable formations during wet seasons for the express purpose of storing water in the natural underground reservoirs for later use. The quantity of available storage room underground depends upon the volume of the porous material between the position of the water-table during the time storage operations commence and the position where the water-table develops undue effluent seepage. Methods employed in water spreading are:

I. Maintaining continuous flow in stream channels.

II. Impounding water in check dams, or by other stream bed improvements.

III. Spreading water through ditches or basins.

IV. Feeding water down wells or shafts.

Section 2-12: Transpiration and Evaporation

2-12.1 Evaporation. Where the water-table is near the ground surface, evaporation from the soil is almost equal to that of evaporation from a free water surface. When the water-table is at greater depths, the loss by evaporation decreases, and becomes negligible when moisture no longer reaches the ground surface by capillary action.

2-12.2 Transpiration. Transpiration is the process by which water as vapor excapes from living plants and enters the atmosphere. Israelson (25, p.301) reports that the rate of transpiration often exceeds that of evaporation from the soil. Meinzer (38, p.109) describes the general occurrence of greater vegetal discharge than soil evaporation due to the ability of roots to lift water from greater depths than is possible by the capillary interstices of the soil. Even in arid regions transpiration may occur over a wide area. In such regions much of the vegetal discharge is accomplished by plants of but few dominant species.

2-12.3 Determining Rates. Tolman (60, p.85) reports it is possible to determine only approximately the amount of evaporation and transpiration over an entire watershed. Considerable experimentation has been made under laboratory conditions to obtain some basis for estimation. However, such determinations lack accuracy because of the complex conditions which control plant growth in its natural environment.

CHAPTER III

HYDROLOGY OF GROUND WATER FROM SPRINGS

The term "spring" may be applied to any water freely emerging from the ground at a single point or within a restricted area. The distinction between springs and effluent seepage is not always pronounced. There are many gradations between the concentrated outflows characterizing true springs and the diffused emergence of water over large areas.

Section 3-1: Classification of Springs.

3-1.1 Because of the complex interaction of the many factors in spring formation, there is today no satisfactory general classification. Tolman (60, p.445) is of the opinion that no universal classification will ever be developed. Spring classification has in the past been by the salient features that have impressed each geologist during his investigation.

3-1.2 Classification by Size. Miezner's (33,pp.47-50)classification of springs according to size is as follows:

Magnitude	Average
First	100 sec.-ft. or more
Second	10 to 100 sec.-ft.
Third	1 to 10 sec.-ft.
Fourth	100 g.p.m. to 1 sec.-ft.
Fifth	10 to 100 g.p.m.
Sixth	1 to 10 g.p.m.
Seventh	1 pt. to 1 gal. per minute. About 200 to 1500 gal. per day.
Eighth	Less than 1 pt. per minute. Less than 200 gal. per day.

3-1.3 Classification by Formation. Springs may be classified according to the type of water-bearing formation from which the ground water emerges. Tolman (60,pp.444-461) describes six formation classes:

I. Springs issuing from permeable veneer formations.

II. Springs issuing from thick permeable formations.

III. Springs issuing from interstratified permeable and impermeable formations.

IV. Springs issuing from solution openings.

V. Springs issuing from lava.

VI. Springs issuing from fractures.

3-1.4 Babbitt and Doland (2, p.121) describe three basic types of springs. The first results from an overflow of the ground water-table onto water-table lands. This type of discharge often takes the form of diffuse seepage. The second results from the encountering of an outcropping impermeable stratum by percolating water. This type of discharge is often termed a contact spring, as its point of discharge occurs at the upper contact of the impermeable stratum. The third type of spring results from the escape of ground water which has been held under pressure beneath an impermeable stratum. This type of spring gives rise to what is called an artesian spring.

3-1.5 Classification by Continuity of Flow. Classification according to continuity of flow is as follows:

I. Perennial springs are those that discharge throughout the year.

II. Intermittent springs are those that discharge throughout a portion of the year after prolonged rains.

III. Periodic springs are those that discharge at intervals not directly related to the occurrence of rain.

3-1.6 Gravity, Artesian, Seepage, Tubular, and Fissure Springs. Gravity springs are those whose water is not confined between impermeable beds, but flow from the aquifer under the action of gravity. Tolman (60, p.448) suggests the term gravity spring as not a satisfactory classification designation as all springs, except possibly some thermal springs and those containing large quantities of dissolved gases, are brought to the surface by gravity. Artesian springs are those whose waters are confined in impermeable beds, and are under hydrostatic pressure because the water level at their source is higher than at point of emergence. Seepage springs are springs in which the point of emergence is not concentrated. Seepage springs commonly occur where valleys are cut downward into the zone of saturation of a more or less uniform water-bearing deposit. Fuller (14, p.23) states that seepage springs are commonly of the gravity type; but where channels or fissures emerge beneath beds of sand or gravel the seepages sometimes result from true artesian springs. Tubular springs are usually of the gravity type, but are sometimes under artesian pressure. Fissure springs include those issuing from joint, cleavage, or fault planes. The distinguishing feature is a break in the rocks along which the waters can pass.

3-1.7 Contact Springs. Bennison (5, p.66) suggests the term contact springs as a classification. This is a general term used to imply spring flow from permeable material overlying the outcrop of less permeable material retarding or preventing the downward percolation of ground water, causing it to appear at the surface. Springs of Classes I and III, paragraph 3-1.3, are often of the contact type.

3-1.8 Thermal Springs. The thermal springs issue warm to hot water brought to the surface through pressure produced by agencies deep within the earth. These springs are usually uniform in discharge, having little if any seasonal fluctuation. They often occur along faults or other similar geologic conditions. The division between thermal and non-thermal springs as suggested by Tolman (60, p.441) is between 20°F to 25°F above the mean for the region.

Section 3-2: Occurrence of Springs.

3-2.1 Factors Effecting Spring Flow. Five important factors controlling the location of springs, the direction of movement of the effluent water currents, and the quantity of water flowing from springs are:

I. Permeability of the soil at the ground surface.

II. Permeability of the water bearing formations.

III. Rainfall patterns.

IV. Topography.

V. Geologic structure.

3-2.2 Hydraulic Gradient. Springs are formed when the hydraulic gradient of the underground water intersects or passes above the ground surface, provided the water-bearing strata is permeable. Springs are sometimes produced by outcrops of impermeable strata overlaid by permeable water-bearing deposits, or by the occurrence of spring flow from cracked, fissured or cavernous rocks.

3-2.3 Origin of Spring Water. The majority of springs is non-thermal. The average temperature of spring water approximates the average temperature of the superficial rock. This indicates that the water feeding the spring is either not of deep-seated origin, or that the water movements are so slow that the water has cooled to the temperature of the surface rocks through which it passed as it approached the surface.

3-2.4 Seepage. Diffuse effluent seepage may occur without actually forming springs. Effluent seepage starts at the intersection of the water-table with the ground surface and continues throughout the area in which the water-table is at the surface. The upper limit of the water-table may be indicated at the surface by a marked change in vegetation, or the upper edge of a permanently moistened area.

3-2.5 Tolman (60, p.435) states that slow seepage may be accompanied by outflow sufficiently localized to form springs. These types of springs often are located near the upper edge of the area of effluent seepage, and mark the outcrop of the water-table. Springs issuing from thick pervious formations, Meizner's Class II, may be of this type.

3-2.6 Capillarity. Capillary rise may bring water to the surface of the ground, but will not necessarily form ground-water springs. Such an occurrence, however, may indicate a readily available source of groundwater.

Section 3-3: Spring Development.

3-3.1 Increasing Discharge by Development. Although the occurrence of springs may present a readily available source of ground-water for utilization, only a small proportion of the springs of the world is developed to full capacity. Even in the semi-arid and arid regions, springs have been rarely fully developed. Spring water is allowed to be wasted by evaporation and transpiration, or to be polluted by men and animals. Tolman (60, p.462) describes the development and diversion of water from a spring orifice as often involving little or no geological investigation, and requiring little engineering work, except possibly improvement of the spring orifice and installation of necessary diversion ditches or conduits.

3-3.2 Bennison (5, p.65) reports that the flow of springs cannot be increased much beyond their natural ability to flow. Baker and Conkling (3, p.306) suggest that if the spring forms the only outlet for ground water tributary to it, that development will provide only temporary discharge increase. They report, however, that if the orifice discharges only a portion of the tributary water, with the remainder passing on to other springs or discharged in some other manner, then development may result in a permanent increase of flow.

3-3.3 Estimating Discharge. The fully developed discharge of a group of springs is often difficult to estimate because diffuse seepage may furnish a considerable portion of the available water. Where this occurs, Tolman (60, p.462) suggests that the total amount available be estimated by a measurement of the area of the swamp or drainage-way fed by the diffuse effluent seepage, and a determination of the transpiration coefficient of the vegetation in the area by either actual experiment or by evaporation and transpiration studies reported in literature. This quantity added to the water measured as drained from the existing swamp or drainage-way will give an estimate of the total supply of available water in the developed spring system.

3-3.4 Development Practices. The objectives in spring development are to collect or contain the natural discharge of the effluent seepage and to prevent its contamination. The design of the best type of structure for collecting and protecting the water from a spring requires ingenuity and a knowledge of the conditions of underground flow. The design must be guided by the conditions encountered.

3-3.5 Springs issuing from rock, or those issuing at a localized area are usually not difficult to develop. The full development of a group of small springs and the accompanying diffuse effluent seepage may require a geological investigation to determine the source of the water, and an application of methods of drainage engineering practice to collect and to conduct the water to the place of its intended use.

3-3.6 Development of diffuse seepage from thick permeable formations can be secured by constructing a cut-off trench along a contour at or near the point of appearance of the spring. The deeper the intercepting trench, the greater will be the certainty of continuous flow. In this manner, the saturated ground above the bottom of the trench will act as an impounding reservoir to compensate for fluctuations of the ground water-table. The ditch should be dug to a depth required to prevent discharge of water to the surface by capillarity, and should extend a sufficient length to intercept the entire amount of water issuing from the exposed water-table. The ditch may be open, but preferably it should be lined with perforated conduit and backfilled with clean sand and gravel.

3-3.7 Developed springs issuing at the contact of an impermeable barrier often do not have discharge rates as high as the type described above in paragraph 3-3.6. The concentrated contact springs often have a relatively small amount of underground storage. The flow from them may be uncertain and likely to diminish markedly during prolonged drought. Such springs may be developed by construction of an intercepting trench. There is no advantage in constructing the bottom of the trench below the upper contact of the impermeable stratum, as no additional water could be secured.

3-3.8 The spring should be stripped of all vegetation, and have provision for drainage or removal of surface water. Masonry walls of the structure should provide convenient entry, and protect the water from contamination for immediate outside sources. Babbitt and Doland (2, p.125) caution about withdrawing water in such a manner to remove sand with the water. Removal of the fine material may cause underground movements which might divert the underground flow. The flow from springs may sometimes be increased without solids removal by construction of an infiltration gallery at the site of the spring.

3-3.9 The flow of water from a spring is dependent upon the hydraulic gradient of the water-table. Any attempt to gain elevation for a water supply by elevating the discharge pipe from the spring may result not only in a decrease in yield, but may cause the spring to emerge elsewhere. Outflow from the encasement should be unrestricted. This usually means pipe one inch or more in diameter should be used. The encasement should be fitted with a drain pipe and valve to permit cleaning. Both outflow and overflow pipes should be screened to prevent entry of rodents.

Section 3-4: Contamination and Protection.

3-4.1 Destruction by Stock Access. One of the most common causes of destruction and contamination of springs in farming districts arises from the failure to fence the springs to prevent access of stock. A good spring requires permeable soil in the outcropped zone of saturation. Compaction of the moist and wet earth in an area of spring discharge or effluent seepage by the constant tramping by hooves of livestock may permanently destroy a spring. If, by chance, the flow is not entirely arrested, the spring is surely to become unfit for human use.

3-4.2 Effect of Permeability. Fuller (14, p.24-25) describes springs issuing from sands, sandstones, clays, shales and slates as seldom polluted, except where contaminating matter penetrates through cracks or fissures, or through the material itself where the natural covering over the water is very thin. Usually such pollution occurs only where houses, barns, privies, or sewage systems are location on higher ground near the spring. Where polluting material enters the zone of saturation through very porous soil or sinks, the contaminate may remain potent for long distances.

3-4.3 Effect of Surface Drainage. Springs that discharge waters received entirely or in part from upstream swamps or surface drainage-ways are subject to contamination and pollution by all the mineral and organic substances in solution. Fuller (14, p.25) advises against the use for domestic use those springs where their location normally exposes them to inflows of surface water. If other sources are not available, the spring should be carefully protected by water-tight wall. The retaining barrier should be carried to a sufficient height to keep out any immediate surface water.

3-4.4 Placing of buildings or allowing unlimited access adjacent to springs should be avoided. The user of a spring for domestic water must investigate any drainage-way that appears above the spring orifice. A spring may appear remote from any immediate source of contaminate, but owing to the fact that the underground stream feeding the spring appears at the surface at a number of places above it, the water issuing from the spring may be unsafe.

3-4.5 Pollution Through Lids and Covers. Except that it keeps the larger animals out and is a convenience for use, ordinary plank coverings of spring catchment basins or shallow wells offer little improvement. Cracks and crevices almost invariably exist through which small animals may find access. Dirt washing through the cracks by drippings may be almost equal to that entering through an open top. Moreover, such dirt is often the most dangerous type, for it may include the filth from domestic fowls and from the shoes of persons coming from manured yards.

3-4.6 Springs producing water from shallow sources may be considered to be subject to the same dangers of pollution as are shallow wells. Likewise, deep springs may be considered to be subject to the same conditions of pollution as are deep wells, that is they are generally excellent sources of water if protected at the orifice. Occasionally they may be subject to deep percolation of polluted water. If such is the case, the supply should be continuously treated or abandoned.

3-4.7 Danger of Lead Conduit. Conduit or pipe made from lead should be avoided in spring development. Lead, which has been formerly more commonly used in pipe manufacture than now, is more or less readily dissolved by soft waters. Where water flows constantly there is little danger of lead poisoning. If, however, the flow is shut off when not in use the use of lead pipe is particularly dangerous.

CHAPTER IV

HYDROLOGY OF WELLS

A water well is a vertical excavation from which ground water is obtained. Tunnels, drifts, horizontal boreholes from vertical shafts and various types of sub-surface drainage structures are also used for collecting ground water.

Section 4-1: Classification of Wells.

4-1.1 Classification by Method of Sinking. Dug wells are those where excavation is made by use of shovels, either manual or mechanical. Bored wells are excavated by the use of hand or mechanically powered augers. Driven wells are constructed by driving a casing having a sharpened drive point at its lower end. Drilled wells are excavated by either percussion or rotary drills, the excavated material being brought to the surface by a bailer, sand pump, hollow drill tool or by hydraulic pressure.

4-1.2 Classification by Type of Finishing. Cased wells are lined with iron or steel pipe, sheet iron or steel casing, brick, concrete tile, wooden cribbing, etc. Cased wells are further classified according to the type openings provided by the casing for entrance of water. Open-end wells have no screen or perforations at the lower portions of the casing, the water entering only at the lower open end of the tube. Screened wells utilize some sort of screening device at the lower portion of the casing to allow entrance of water, but prevent infiltration of the coarser sands into the well. The screened wells are of two types. Naturally screened wells, sometimes referred to as natural gravel-packed wells, penetrate into a water-bearing formation of larger or closely graded particle size. The fine material around the screen is removed through the screen by use of proper well developing equipment. See paragraph 4-4.17. The artificially screened wells penetrate into an aquifer so fine and closely graded that gravel must be placed around the perforations to protect the well against the infiltration of the fine native materials.

4-1.3 The uncased wells penetrate sub-surface formations that are so hard and stable, that no casing of any kind is required. Uncased holes are sometimes stabilized chemically, an example being the addition of either cement or bentonite into the hole during drilling operations.

4-1.4 Classification by Position of Water-Table. Wells may be classified according to their relative position with the regional water-table. Perched wells tap water held above the water-table by a more or less impermeable stratum. Water-table wells draw on free ground water. Confined ground water wells yield water received from sources of confined ground water, and are further classified as described in paragraph 2-10.5.

4-1.5 Other Methods of Classification. Classification of wells can be made from several other standpoints.

I. Open wells are those three feet or more in diameter. Tubular wells are usually thought of as being two feet or less in diameter.

II. Wells may be classified as being deep or shallow, depending upon the depth of the formation from which the water is obtained. Combination wells are those obtaining water from both shallow and deep formations.

III. Thermal and non-thermal classifies the well according to the temperature of the issuing ground water. See paragraph 3-1.7.

IV. Wells may be classified according to the general type of aquifer formation, either consolidated or unconsolidated rock. See paragraph 2-6.7.

Section 4-2: Methods for Locating Proposed Wells.

4-2.1 Water-Witching and Dowsing. Divining, water-witching or dowsing is a term applied to the extra-sensory ability reported of some persons to locate underground sources of water. It has been used for this purpose and others for centuries, being mentioned many times in the Bible and in writings from the ancient civilizations of the Romans, Greeks, Persians, Chinese and others. During the seventeenth century its use spread to England and elsewhere on the European continent.

4-2.2 Many different variations of divining materials and methods of their use exist. Regardless of the success that may be claimed by these methods for locating underground water, there is no scientific evidence to support their use.

4-2.3 Geological Field Data and Well Log Interpretation. Information providing an inexpensive but valuable indicator for the probable success of a proposed well may be obtained from the exposed geology of the area, and from the history of wells previously constructed in the vicinity. A trained observer may associate apparent geological evidence with the underground formations. The use of such methods will depend upon prevailing topographic and climatic conditions, and upon supplemental geological evidence with the underground formations. The use of such methods will depend upon prevailing topographic and climatic conditions, and upon supplemental geological information available from other sources such as existing test holes or wells. Such a study may be limited to only a casual observation of topography, outcrops and well records; or it may involve a detail study by a trained geologist or hydrologist of all geological and well log data available.

4-2.4 Surface irregularities of the area usually influence somewhat the location of the water-table. The tendency for the water-table to be a facsimile of the surface topography is described in paragraph 2-7.6. In a general way, the prevailing direction of ground water flow is with and towards the main surface drainage-ways. Wells drilled upon plateaus surrounded or abutted against deeply cut canyons are often doomed to failure, or require depths beyond economic feasibility. The deep water-table usually found in deeply eroded topography is described in the paragraph previously mentioned. Stearns (53, p. 195) describes an earnest but unwise effort to obtain water in the Deschutes formation by drilling to a depth of 210 feet, while less than a half mile away the Deschutes River had scoured a canyon 750 feet deep. Had but only the rudiments of a geological investigation been made, the owner would have foreseen the folly of such a drilling venture.

4-2.5 Extensive outcrops of sub-surface strata may provide an inexpensive yet informative picture of the geology for underlying formations. Information regarding porosity, permeability, faulting and fracturing, and the extent and relative positions of the strata may be obtained from an examination of exposed strata. This information correlated with the relationships of occurrence of ground water is outlined in Chapter III.

4-2.6 Evidence of prolonged erosion or alluvium in an area may give a trained observer information regarding occurrence of ground water. Investigation of hills and natural drainage-ways usually reveals if erosion or deposition was extensive or limited to a small area, the manner in which it was moved or if initiated by geologic failure of the earth's crust. The occurrence of slides gives evidence to the type of underlying formations, usually indicating the presence of a generally impermeable stratum.

4-2.7 The observation of effluent seepage in an area is probably the most direct apparent source of information of the water-table. The upper contact of effluent seepage locates the water-table. The experienced observer may be able to associate with considerable accuracy the various types of effluent seepage to the existing formations and to the character of the water-table in the area. See paragraph 3-1.3. Annual and secular climatic patterns may provide information on the general rate of influent and effluent seepage of the region.

4-2.8 Although records from existing wells are potentially a valuable source of geologic information for the location of other nearby proposed wells, the data from existing well logs are often so sketchy and incomplete as to be practically worthless. If at the time the existing well was drilled sub-surface samples were carefully taken and recorded, and the action of the water-table recorded during drilling, a valuable log of the underground strata and of the water-table would be preserved. And if the static head of the existing well is measured periodically, the additional information regarding the regional water-table and the aquifer in which it acts would be of use not only to the owner of the existing well but to others proposing wells nearby. The subject of well logs is discussed further in Section 4-3.

4-2.9 The value of geologic field data and interpretations from existing well logs as a method for location of underground water will depend upon the amount of such information that is available, the degree of skill used in analyzing this information and the required capacity of the proposed well. The principal advantage to its use is probably its low cost. It represents the least costly method of exploration where some degree of scientific reasoning is used. But because the conclusions obtained from such a study are often of such a general and preliminary nature, their usefulness may be better directed toward recommendations for a systematic program of test hole drilling. This would be especially true where proposed wells are to be located in an area known to be deficient in water.

4-2.10 Test Holes. Test holes are any holes put down for the express purpose of determining geologic information. They include all holes put down by any standard method such as drilling, digging, boring and jetting. Hydraulic, percussion or rotary equipment may be used. If it has been decided to utilize a test hole program prior to drilling operations, the test holes should be preceded by a thorough geologic study based on exposed strata and existing well logs. Bennison (5, p. 85) lists four requirements for test work:

I. "A sufficient number of test holes should be put down to determine the thickness, area, and location below the surface of each water-bearing stratum within the depth and influence of the proposed well or wells.

II. All prospect holes should be at least two inches in diameter, and all test holes should be at least four inches in diameter. Test holes should be put down by the use of methods that will insure natural samples.

III. All samples should be properly labeled and the log of the ground for the surface to the bottom of the hole accurately determined and recorded, together with all notes concerning the raising or lowering of position of the water-table.

IV. Analyses of formation samples shall be made in laboratories maintained and equipped for that purpose, and all estimates be made by someone familiar with the hydraulic principles of water-bearing rocks and formations."

4-2.11 Test holes should not penetrate into a saturated material more than a few feet in order to prevent an artesian condition. Water-bearing materials are rarely homogeneous, occurring in layers of varying permeability. If the dip of these strata or layers is in the direction of the water-table slope, slight artesian pressure may develop. Such effects are usually very small for layers only a few feet below the water-table and are therefore neglected. As the hole is drilled down deeper, the change of static level in the hole as the hole progresses should be noted.

4-2.12 Bennison (5, p. 83) describes the use of test hole programs as the most reliable way of securing underground information. Because test work is such a vital phase of ground water development, the importance and size of the proposed development often determines the amount of test work that should be done. The formations which are to be penetrated determine the type of test hole to insure natural samples. The use of fully cased holes is suggested. Unless it is definitely known that subsurface conditions are uniform over a large area, conclusions based on one or two test holes may be misleading. Conclusions based on an ill-advised test hole program have no more value than guesses.

4-2.13 Geophysical Methods. Measurements indicating the relative difference in either density, magnetism, elasticity or conductivity occurring in the saturated and the unsaturated formations are the basis of the geophysical methods of ground water location. Differential measurements of either of these four physical characteristics of subsurface formations may be interpreted by either of two methods, structural interpretation or stratigraphic interpretation.

4-2.14 The object of a structural investigation is to locate underlying structural unconformities, such as troughs, faults, declines or other areas of general depression. It is applicable where the relation of the occurrence of water to detectable beds has been previously established. Instrumentation detecting any of the four physical differences previously mentioned may be used for structural investigation. However, practical considerations limit the use of some of them. Magnetic and gravimetric sensing instruments are either too slow, lack portability or yield generally unreliable field data. Heiland (60, p. 272) reports that for structural investigations, seismic and electrical conductivity methods are most universally used.

4-2.15 The object of a stratigraphic investigation is to determine the depth to the aquifer itself, and to investigate its characteristics. Stratigraphic investigations can in general be made only with elasticity and electrical conductivity sensing instruments. Heiland (60,pp. 267-270) describes the seismic instrumentation, either seismic refraction or binaural geophone detection, as being more expensive than the electrical methods; but they have greater safety in the interpretation of results and have great application.

4-2.16 Geophysical methods have been pioneered and developed primarily for use in the petroleum industry. Bennison (5, p. 91) describes these methods as being not adapted particularly for the water investigations, and that it will be many years before this method will be used extensively in water development work. Geophysical investigations do not replace studies of test holes and wells to determine permeability and specific yield of sub-surface strata, direction and movement of ground water, location of the water-table, etc. Information obtained is more extensive but less exact than that received from either test holes or good well logs. It is seldom that yields can be predicted from geophysical data, unless wells exist nearby which penetrate into formations having known capacity. Its immediate value appears to be in providing information that will supplement geologic deductions concerning sub-surface formations.

4-2.17 Geophysical methods are seldom economical for the location of a single or even a few wells. Its application to ground water development is often commercially unattractive. Expensive apparatus and highly trained operators are required for the field work. Field data must be interpreted by geologists and hydrologists. Costs frequently exceed those of surface geological surveys, and for small projects, the cost of the investigation may approach or exceed the expense of drilling. At present, geophysical testing is feasible for ground water investigations only on the most important and extensive projects, and when other means are not available.

Section 4-3: Well Logs.

4-3.1 The Importance of Well Logs. An accurate written account of all phases of ground water development is important. This includes a complete description of formations encountered in drilling of test holes and wells, description of static levels during drilling, pumping tests and observation of static level of operating wells. Such information has value not only to the user of an existing well, but to the owner of a proposed well. Standard forms available from state or federal agencies are provided for this purpose.

4-3.2 Accuracy of the Log. The data for the log are to be carefully taken and recorded in full on standard forms. Information appearing should include:

1. Date of construction.
2. Driller's name and address.
3. Owner's name and address.
4. Location of the hole, topography and ground elevation.
5. Type of drilling equipment used.
6. Diameter of hole.
7. Size, type and extent of casing.
8. Description of packing and sealing used.
9. All details as to type of screen or perforation and description of any gravel treatment.
10. Description of any well development.
11. Complete description of static-level fluctuations during drilling.
12. As complete and accurate description of the formations encountered during drilling as possible. Sieve analysis is preferred.
13. Pumping test, showing description of test pump used, yield, draw-down, recovery time, etc.
14. Water quality analysis.
15. Description of pump installed.

4-3.3 Short time pumping tests are often misleading. Bennison (5, p. 204) suggests that 24-hour continuous tests of wells are not long enough, that 30-day tests are much more likely to give reliable results.

Section 4-4: Drilling Methods and Equipment.

4-4.1 Dug Wells. These type wells, dug either by hand tools or by powered excavation buckets are usually lined with timber cribbing, masonry curbing or concrete or steel casing for the full length of the hole. Hand digging below the water-table must be accompanied with pumping. When pumps used during construction fail to keep ahead of water inflow to the well, further excavation becomes impossible. Such wells for rural use are usually three to six feet in diameter. Dug wells using powered excavation buckets are not so restricted in depth as are the hand dug holes. When using orange peel or sand buckets, pumping during excavation below the water-table is not necessary. Excavation can continue far below the static water level of the well. The depth to which a wet hole can be excavated is limited only to the amount of skin friction of the formation against the casing, or by the depth of the first hard stratum that prevents further digging. It is much safer and easier to dig a wet hole, than it is to attempt to pump the water out and do the excavation under dry conditions. The danger of heaving is eliminated by allowing the water column in the well to stand at its static level.

4-4.2 Dug wells, whether the diameter be as small as three feet or as large as 30 feet in diameter, or whether it be dug by hand or by powered buckets, still have a popular appeal. The idea often prevails that such wells are cheaper, they are easier to construct or that because of the large diameter they have superior capacity. Although many of the dug wells constructed years ago are still dependable wells, modern drilling equipment will usually produce a better well at less cost. The benefits derived from a large diameter well are often over rated. See paragraph 4-8.3.

4-4.3 Care should be used in locating a dug well to prevent possible pollution. The upper portion of the curbing should be watertight. Particular care should be taken to prevent the possibility of surface seepage down the outside of the well curbing. Dug wells penetrating into the shallow ground waters only are particularly susceptible to pollution from surface contaminants.

4-4.4 Bored Wells. Wells penetrating soft unconsolidated materials may be excavated by either hand or powered augers. The size of the hole may vary from two inches to as much as two or three feet in diameter. Material is loosened by the rotating auger, and is brought to the surface by either pulling auger or by using a sand pump or bailer. Augers work best when excavating into formations that will not cave in. Usually casing is required soon after the hole reaches the water-table.

4-4.5 Bored wells are still being constructed, but are usually not used to develop large quantities of water. Although bored wells have been excavated to depths exceeding 400 feet, their use is now confined generally to the shallower and smaller holes yielding small water supplies.

4-4.6 Driven Wells. A well obtained by driving a casing, at the lower end being a sharp driving point and a perforated section or screen, is called a driven well. A protecting cap known as a drive head is clamped on the pipe near the ground surface and receives the driving impact, either from a hand sledge or from some type of drop hammer. Additional lengths of casing are added during the driving operation.

4-4.7 In general, driven wells are satisfactory where small supplies are adequate, and where the water-bearing formations are overlain by shallow and penetrable beds. The average well points used for domestic wells are from one-and-a-half to three inches in diameter. Because of small diameter and screen area, the capacity of a driven well and the type of pumping equipment installed is limited. If the pump cylinder is attached directly to the top end of the pipe, the static water level must be within 20 or 25 feet of the ground surface. Driven wells cannot satisfactorily penetrate rock, heavy beds of clay or hardpan.

4-4.8 Larger diameter points can be driven by a "washing in" or jetting method. This hydraulic method of driving in a point has the advantage of speed when sinking the larger points to greater depths, but requires more equipment. The hydraulic method also minimizes the possibility of injury to the point or clogging of the screen.

4-4.9 The use of well points is usually not recommended for the development of permanent water supplies. They do have some very favorable advantages such as low initial investment in terms of labor, materials and equipment. The drive points and casing are completely recoverable and may be used repeatedly in several different locations. Well points can be installed in groups or relays. Being interconnected, the disadvantage of low capacity per well point may be partially overcome. Provided suitable penetrable formations overly the water-table, driven wells are usually satisfactory for temporary water supplies, isolated dwellings or stock water.

4-4.10 Hydraulic Rotary Drilled Wells. Rotary drilling equipment utilizes the cutting action of a rapidly rotating cutting bit attached to the end of the string of drill pipe. The material dislodged by the bit is removed from the hole by mud fluid that descends through the drill pipe and ascends outside the pipe. The fluid carries the broken fragments to the surface in suspension. The rotary drilled hole is drilled to the bottom before the casing is installed. The thick fluid mud minimizes the occurrence of cave-ins, but has the adverse effect of tending to seal the water-bearing formations.

4-4.11 Tolman (60, p. 403) describes the increased use of rotary equipment in water well drilling as being partially due to the development of the gravel-envelope well. This type of well as drilled by rotary equipment is drilled or reamed to about twice the diameter of the casing to be used. The casing is made up at the surface having perforated sections opposite the water-bearing strata. Casing is then installed and centered in the hole, the space between the casing and well wall is filled with sorted gravel. As the gravel is fed down outside the casing, the rising fluid mud prevents the settling gravel from lodging and bridging prematurely. A plunger is run into the casing simultaneously with the addition of the gravel. As the plunger is rapidly moved up and down, the gravel is added and the thinning mud gradually cleared by the addition of clear water. As the fluid mud gradually thins, the surging of the plunger washes the plastered mud from the walls of the drilled hole. This enlarges the bore of the hole in the water-bearing formations, the material is washed away by the surging action and gravel settles in its place. In this way the adverse effect of sealing of the well wall by the fluid mud, described in paragraph 4-4.10, is minimized. To prevent contamination from surface water pollution the well wall is cemented nearer the surface.

4-4.12 Some of the advantages of rotary drilling equipment are:

I. A small diameter test hole can be drilled. If the prospects for water appear poor, the hole can be abandoned at minimum cost. If prospects for water appear favorable the hole can be rapidly reamed to a size desired.

II. Large diameter holes can be drilled.

III. Because casing is installed after drilling, perforations can be placed into the casing before casing is installed. Maximum perforation efficiency is assured.

IV. The method is favorable for the use of the gravel-envelope well.

V. A wide variety of formations can be handled with rapid drilling speed.

4-4.13 Percussion Drilled Wells. These type wells are sometimes called cable-tool wells. The cable-tool equipment dislodges the material by a heavy bit that is repeatedly raised and dropped. The broken and pulverized material in the bottom of the hole is removed by a bailer or sand pump. The casing is usually installed simultaneously with drilling. A casing shoe or starter section at the bottom of the casing leads the way for the entire line of casing above it, and must be strong enough to withstand the driving necessary to force the casing through the hole.

4-4.14 There are many different types, shapes and sizes of bits used in cable-tool drilling. For drilling into the harder formations the bit will have a fairly sharp chisel edge, while for drilling into the softer materials the drill bit used will be almost flat and have but a blunt edge. The bits usually have a shank several inches smaller than the cutting edge, enabling a hole to be drilled slightly larger than the cutting edge. Cable-tools usually have a fluted shape allowing displacement of fluid in the hole as the tool rises and falls.

4-4.15 A variation of the cable-tool method is the California stovepipe method, sometimes called the mud-scow method. The percussion bit is a disk-valve bailer with a sharp cutting edge at the bottom slightly larger than the outside diameter of the bailer. Each time the bit is dropped part of the dislodged material is trapped in the bailer portion of the bit. When the bailer is full, it is pulled from the hole and emptied.

4-4.16 Advantages claimed for the cable-tool drilled wells are:

I. Cable-tool equipment is usually lighter than rotary equipment and has greater portability.

II. For drilling relatively shallow holes in unconsolidated materials the cable-tool well is usually less expensive than that drilled by rotary equipment.

III. Accurate sampling of formations is possible during drilling operations.

IV. It is possible to test the quantity and quality of water from each stratum.

V. Less water is needed for drilling operations than is required by the rotary equipment.

4-4.17 Well Development. Well development is the mechanical improving of permeability and porosity of the aquifer adjacent to the well. The granular aquifers, such as sands, silts and other poorly graded aggregates respond most favorably to well development practices. There are several methods used, but all are based on the action of surging or agitating the water in the formation for the purpose of removing the finer materials near the casing.

4-4.18 Five of the more widely used methods of well development are:

I. Development by explosives utilizes the explosive action to shatter the surrounding formation. This method is most effective in hard, brittle aquifers. It is least effective in the soft and elastic formations, which are bent and compressed during the explosion rather than broken.

II. Development by backwashing or "rawhiding" is a method consisting of starting and stopping the test pump in order to produce rapid changes in the pressure heads in the well. A high capacity pump which will rapidly provide maximum draw-down is most effective. The pumping, stopping and recovery are continued as long as fine material comes from the well.

III. Development by air is accomplished by a series of alternating air lift pumping and air pressure surges. A drop pipe lowered into the well and an air line operate as an air lift. After the well is pumped by the air lift, the pumping is discontinued for a short time to allow the compressor air tank to reach maximum pressure. During this time the air line is lowered slightly below the drop pipe. The air valve from the compressor tank is then opened rapidly allowing air to surge into the well. A brief but forceful surge of water will follow. The air line is then pulled up into the drop pipe, the unit now acting as an air lift. The alternating series of surges and air lifts are repeated until fine material is no longer removed.

IV. The surge plunger or surge block method of development is any method employing any sort of a piston, plunger or block which when operated in a well casing produces an agitating action. The reciprocating motion of the plunger in the casing produces pressure changes to the formation wall which loosens the fine sand outside the screen, and carries them through the screen. This fine material is then removed by any convenient means, usually by a bailer.

V. Well development by over pumping is not as complete as is possible by the previously mentioned methods. This is especially true in a high capacity well or in a well having a small head differential. Over pumping only clears the well of fine material at the rate of pumping used, and provides little actual improvement of capacity.

Section 4-5: Water-Table Wells.

4-5.1 Definition and Behavior. Water-table wells draw only on free ground water. Pumping from such a well will produce a lowering of water-table adjacent to the well, called a cone of depression. Observations of the cone of depression during a test of a water-table well will provide information regarding character of the aquifer and general hydraulic conditions of the ground water. Highly permeable aquifers will show a flat gradient to the cone of depression, while the tighter and more impermeable material will cause a steeper gradient. The time required to approach a static hydrualic condition is less in water-table wells tapping the more permeable aquifers.

4-5.2 Testing of Water-Table Wells. Provided the cone of depression caused by pumping a water-table well does not reach cones of depression from other operating adjacent wells, there are five hydraulic observations that can be made:

I. The specific capacity of the well can be determined. The unit of this measurement is number of gallons yielded per foot of draw-down. Permeability of the aquifer and frictional resistance at the entrance to the well determines specific capacity.
II. Maximum quantity of water pumped from the well in a given time can be established. This is a quantitative figure, without respect to either size of the well or resulting draw-down.
III. The draw-down of the well can be established with respect to a given discharge.
IV. The static level in the well after discontinuing pumping can be established.
V. Rate of recovery can be established. This provides information relative to the permeability of the aquifer.

4-5.3 Movement of Water in the Cone of Depression. Movement of water toward a water-table well is perpendicular to the contours of the water-table within the cone of depression. As long as withdrawals are light the radius of influence due to draw-down will remain small, and water which in its natural course does not flow near the well will not be diverted. As withdrawals become heavier and the radius of influence becomes larger, a greater amount of water becomes diverted towards the well. Adjacent to the well, the gradient of the water-table in the cone of depression becomes steeper, as must also the velocity at which the water travels.

4-5.4 Interference. When cones of depression from adjacent water-table wells overlap, optimum capacity of a well is reduced. Even the smallest withdrawal from any water-table well produces some draw-down, and must display a cone of depression. The larger producing wells display larger radius of influence. Bennison (5, p. 213) suggests that the minimum spacing for prevention of interference in poorer wells is about 200 feet. Minimum spacing to prevent interference of the larger capacity wells may be as much as a mile. The most favorable arrangement for a number of wells is in a straight line at right angles to the direction of underground flow.

Section 4-6: Confined Wells.

4-6.1 Definition and Behavior. Confined water wells withdraw confined ground water. Pumping of confined water has no effect on the overlying water-table. It does cause a reduction of hydraulic pressure within the confined conduit adjacent to the well, and this causes confined water movement toward the well. The depression of the pressure surface by pumping a confined well is called the cone of pressure relief, and is somewhat analogous to the cone of depression found in the water-table well. The cone of pressure relief does not indicate a depletion of stored water from the pressure conduit in the vicinity of the well, as the conduit normally remains fully saturated with water at all times.

4-6.2 Movement of Water in the Cone of Pressure Relief. When pumping is started in a confined well, there is an instant lowering of pressure in the confined aquifer adjacent to the well. This pressure change is effective immediately. If the confined aquifer is rigid, the wave of pressure change moves outward from the well very rapidly. Water movement towards the well begins simultaneously. If the rate of replenishment to the confined aquifer is equal to the rate of pumping from that aquifer, the pressure surface will remain constant. If withdrawals are in excess of natural replenishment to the confined aquifer, there is a continuing lowering of the pressure surface. This may eventually result in a depletion of the confined water.

4-6.3 Elastic and Non-Elastic Formations. Pumping reduces the hydraulic pressure acting against the overlying confining stratum. Additional weight from the overlying formations then bears on the confined aquifer. If the aquifer is compressible, as is the general case, the reduction in pressure in the conduit causes the aquifer to contract. If the contraction is elastic, the conduit will expand back to its original porosity after withdrawals stop. If however, the aquifer is compressed inelastically, only a portion of the reduction of pore space is recovered after pumping stops.

Section 4-7: Perched Water Wells.

4-7.1 Definition and Behavior. Frequently an impermeable stratum exists above the regional water-table and intercepts the downward movement of water through the zone of aeration. If this intercepting barrier is sufficiently extensive, it may hold usable amounts of sub-surface water. Wells tapping these sources are often not dependable, have small capacity and go dry during the annual dry cycles. The perched water-table is a false water-table, and is always higher than the water-table indicating free ground water.

4-7.2 Perched Water on Volcanic Ash or Tuff. Stearns (54, p. 65) describes perched water on more or less continuous beds of ash and tuff. Extensive ash beds occur in the Kau district on the Island of Hawaii. Water moves rapidly downward through the overlying basalt. The water then being perched on top of the impermeable ash beds, flows along its upper surface to a main drainage channel and finally emerges as cliff springs. The perched water is described as being irregular in occurrence owing to the variation in thickness and extent of the ash beds, and to the abrupt changes often encountered in the permeability of the ash. A method of perched water recovery is described which consists of constructing tunnels at the contact between the ash and basalt. The tunnels being perpendicular to the old drainage lines of the surface on which the ash was deposited, have been found to be effective in recovering small bodies of perched water.

Section 4-8: Factors Influencing Discharge of Wells.

4-8.1 Aquifer Characteristics. The effect of permeability, porosity, replenishment rate, climate and topography upon the occurrence of ground water is discussed in Section 2-6. While efficient ground water development requires the consideration of these natural factors, there are also physical aspects of well construction that influence discharge. These are well diameter, well depth, casing perforations, well spacing and well development. Well spacing and well development practices are discussed in paragraphs 4-5.4 and 4-4.17.

4-8.2 Mathematical Expressions for Well Yield. Analysis of the hydraulics of a well show the following relationship: Let,

Q = discharge.

K = permeability coefficient, a function of permeability and porosity.

H = static head, distance from bottom of well to static no discharge level.

h = distance from bottom of well to static pumping level outside the casing.

T = thickness pentrated into confining aquifer.

R = radius of influence, either due to cone of depression or due to cone of pressure relief.

r = radius of the well casing.

H-h = drawdown.

Yield from a water-table well, $Q_w = \frac{K \cdot (H^2 - h^2)}{\log R/r}$

Yield from a confined well, $Q_c = \frac{2 \cdot K \cdot T\ (H - h)}{\log R/r}$

4-8.3 Relation of Well Diameter to Yield. The advantages of large diameter wells are generally over rated. It is true, that some increase in yield accompanies an increase in well diameter, but not in direct proportion. Mathematical analyses show, and field observations have been in agreement, that significant increases in well diameter cause little increase in well discharge. Both confined and unconfined wells have discharge inversely proportional to the logarithm of the quantity: radius of influence divided by the well diameter.

4-8.4 This mathematical relationship means that if two wells are constructed in the same formation, drilled to the same depth, pumping against same draw-down, have equal radius of influence, have everything the same except their diameter; that a 24" well would yield only about 20% more than would a 6" well, or that a 48" well would yield only about 32% more than a 6" well (based on radius of influence of 2000').

4-8.5 Wells drilled into more impermeable aquifers, such as clay or till, are usually improved by increasing their diameter. For an extremely dense formation the amount of water entering the well may be nearly proportional to the area of surface exposed in the well. Large diameter wells may be desirable in rocks where water occurs in pores rather than open passages. In these type aquifers permeability is low, the well displays a steep cone of depression or cone of pressure relief, and the radius of influence is small. Assuming a radius of influence of only 100' in such conditions, a 24" well would yield about 32% more than would a 6" well, a 48" well would yield about double that of the 6" well.

4-8.6 The conclusion is drawn that increasing the diameter of a well increases yield appreciably only in those wells penetrating the more dense water-bearing formations. In coarse granular aquifers, or in formations holding water in extensively interconnected bedding or joint planes, the diameter of the well is not so important. It is true that increasing the well diameter reduces entrance loss at the casing perforations, and reduces the sand carrying capacity of the water. From economical considerations, these two problems can usually be better solved by perforation improvement, or by use of well development techniques. See paragraphs 4-4.17 and 4-8.10. Minimum casing diameter may be governed by the type of pumping equipment that is to be installed.

4-8.7 Relation of Well Depth to Yield. In general, the yield of a well is directly proportional to the thickness penetrated into the aquifer. A well penetrating the full depth of an aquifer can yield four times as much as the same type of well which taps only the top 25 percent. Bennison (5, p. 215) cautions about stopping a water-table well short of the full depth of the zone of saturation (within reasonable limits). Money saved in initial cost by drilling the shallower hole is seldom worth the disadvantages of reduced yield and dependability.

4-8.8 Examination of the mathematical equation, paragraph 4-8.2, for yield of a confined well shows discharge to be directly proportional to thickness penetrated into the confined aquifer, and to draw-down $(H - h)$.

4-8.9 Changing the term $(H^2 - h^2)$ in the equation for yield of a water-table well to the value $(H + h)(H - h)$, where $(H + h)$ is roughly equal to $2H$, we can again say that discharge is directly proportional to draw-down. This assumption in the case of the water-table well is valid only where draw-down is small in comparison to the total static head, H, and would generally occur when the well penetrates deep into the zone of saturation. If however, the well penetrates but a short distance into the aquifer, draw-down will probably be a considerable portion of the static head. In this case then, the rate of increase in yield is not linear with rate of lowering of pumping level; the well is a poorer producer.

4-8.10 Casing Perforations. The purpose of screens or casing perforations is to allow a maximum flow of water into the well without passage of the coarser sands during pumping. Perforations should be of a size and shape that do not clog readily. For maximum hydraulic efficiency, the perforations should be uniformly spaced throughout the entire aquifer, and should have a maximum open area consistent with reasonable structural strength. To develop maximum flow, the percentage of perforation open area should be no less than the void ratio of the aquifer.

4-8.11 During pumping, the formation particles tend to settle in and around the perforations. Smaller particles lodging against the openings or bridging around the openings retard flow. If the small particles are caught in the perforations, flow may be entirely stopped. The amount of blocking may vary from a negligible amount to as much as almost complete closure. To allow passage of the small particles that do find their way to the outer casing surface, a long and narrow perforated slot having a sharp and well-defined edge is recommended. Bennison (5, p. 223) suggests that perforations arranged vertically function better than do those placed horizontally.

4-8.12 Perforations may be either factory installed, or field installed. Factory type perforations may consist of heavy screens installed below the casing, or casing having machine-perforated holes. Perforations installed in the field may consist of slots cut with a torch, or perforations made in the hole with a perforator. Of the four types of perforations, those made in the ground by a perforator are least satisfactory. These perforations tend to be oversize, and unevenly spaced. A second pass with the perforator cutter is almost sure to cause overperforation to the extent that the casing is dangerously weakened. Perforations made in the hole are usually satisfactory for wells tapping coarse gravel aquifers.

Section 4-9: Well Contamination.

4-9.1 Contamination from Wells. A well is a direct connection between the surface and the water-bearing formations, and therefore can act as an accessible vehicle for polluting materials. Poorly constructed shallow wells in areas having contaminated surface waters invariably cause pollution of the ground water. Shallow wells are a menace to the purity of the ground water supply when their construction allows access to animals within the vicinity of the well, allows entrance of surface waters because of inadequate surface drainage, or allows refuse or droppings to enter through the top of the well cover. Contamination problems of dug wells are discussed in paragraph 4-4.3.

4-9.2 Sealing. Cased or curbed holes are usually dug slightly larger than the outside dimensions of the inserted casing. This outer annular space, unless sealed off, can be an avenue for pollution. Sanitary well construction requires an impermeable material, usually cement grout, completely filling the annular space for a sufficient distance above the water-table to prevent pollution. The upper end of the casing must be completely sealed to prevent direct entrance of contaminants. There are various methods for grouting and sealing a well. Each method is designed to secure complete closure of the open space outside the casing at prescribed depths above the water-table. Confined wells passing through contaminated confined waters are protected by sealing the casing at the adjacent water-tight formations.

CHAPTER V

CLIMATOLOGY OF THE RESERVATION

Section 5-1: Records.

5-1.1 Weather Stations on the Reservation. Climatology observaations have been recorded continuously at the Agency since 1902, and intermittently at Simnasho since 1938. Records for the Agency weather station are maintained at the Agency Forestry Office, and are apparently not published. Measurements from the Simnasho weather station appear in weather bureau publications of the U. S. Department of Commerce. Both precipitation and temperature records are available for each station.

5-1.2 Weather Stations Adjacent to the Reservation. Weather stations are maintained at Madras and at Rio Hermoso. Measurements from these stations appear in weather bureau publications of the U. S. Department of Commerce. The station at Rio Hermoso is located off the reservation to the southwest.

5-1.3 Compilations. A compilation of monthly precipitation of the Agency weather station and the Simnasho weather station appears in Appendices V-A and V-B. A climatic summary for the Madras, Agency, Simnasho and Rio Hermoso weather stations appears in Appendix V-C.

Section 5-2: Climatic Conditions.

5-2.1 General Description. The climate of the reservation is generally arid, being hot and dry in the summer, and cold in the winter. The lower elevations to the east are drier, receiving less total annual precipitation, but receiving slightly greater percentage of the annual precipitation during the summer months than do those areas to the west and of higher elevations.

5-2.2 Easterly Portion of Reservation. The eastern part of the Metolius Bench, Miller Flat, the Dry Creek area, Dry Hollow and other open areas of lower elevation on the eastern and southern part of the reservation are probably representative of the climate at Madras and at the Agency. Since 1906 the Agency weather station, elevation 1500 feet, received an average annual precipitation of 10.25 inches, 35 percent of which fell during the six-month summer period between April and September. Records kept at the Madras weather station, elevation 2250 feet, for 28 years indicate average annual precipitation of 8.64 inches.

5-2.3 Recorded extreme temperatures at the Agency vary from -38° F. to 114° F. Short periods of below zero are not unusual during the winter. Temperatures frequently exceed 100° F. during the summer. The nights are usually cool, even during the hot summer periods.

5-2.4 A compilation of climatic data based on observations for 24 years at the Agency, appearing in the U. S. Yearbook of Agriculture, 1941, (63, p. 1077), indicates a frost-free period of 140 days extending from May 16 to October 3. A report on file at the Agency office (73) indicates a frost-free period at the Agency to be 104 days (presumably 122 days) extending from May 24 to September 23.

5-2.5 Plateaus and Bench Lands. The tablelands known as Sidwalder or Mill Creek Flat, the western portion of the Metolius Bench, the Mutton Mountains, the Island, and Schoolie Flat are probably representative of the climate at the Simnasho weather station. Since September 1938 the Simnasho weather station, elevation 2400 feet, received an average annual precipitation of 12.89 inches, 28 percent of which fell during the six-month summer period. In these areas of the reservation annual precipitation is sufficient to produce fair grain crops or hay.

5-2.6 Lower Mountain Slopes. Climatic conditions at Rio Hermoso are probably representative of the timbered areas on the lower slopes of the Cascade Mountains. Precipitation measurements taken intermittently at Rio Hermoso, elevation 2100 feet, during the years 1910 to 1919 averaged 18.66 inches annually. Twenty-seven percent of the annual precipitation was received during the summer months.

5-2.7 Cascade Range. The upper portions of the reservation are snow-covered from December to March or April. Below the 3000 foot level, snow in the winter is rarely more than one foot deep. Occasionally winters pass without any snow remaining on the ground for an appreciable length of time. Records are not available at the summit of the Cascades but reports at Government Camp about 50 miles north of the reservation indicate annual precipitation probably exceeds 80 inches. On the higher slopes of Mount Jefferson are glaciers and perpetual snow. The summer snow melt from the higher slopes contributes to the sustained flow of the streams that flow easterly across the reservation.

Section 5-3: Summary.

5-3.1 Annual Precipitation. The average annual precipitation is about 10 inches in the easterly and southerly portion of the reservation. The higher plateau lands lying to the north in the vicinity of Simnasho and Schoolie Flat receive about 13 inches annually. Timbered lands lying on the lower slopes of the Cascades receive 18 to 20 inches annually. Unrecorded precipitation at the summit of the Cascades bordering the west edge of the reservation probably exceeds 80 inches annually.

5-3.2 Seasonal Distribution. Throughout the basinal lands of the reservation, about 30 percent of the total annual precipitation occurs during the six summer months.

5-3.3 Growing Season. The growing season between killing frosts on the irrigable eastern part of the reservation varies from 120 to 140 days.

5-3.4 Supplemental Water. Irrigation is a necessary supplement to the seasonal precipitation for the production of good crop yields.

CHAPTER VI

SURFACE RUN-OFF OF STREAMS BOUNDING AND WITHIN THE RESERVATION

The Deschutes and Metolius Rivers bounding the east and south sides of the reservation, and the streams flowing easterly across the reservation are characterized by remarkably sustained flow and freedom from undesirable detrital materials or chemical substances. Uniformity of flow is chiefly due to the large underground storage of water in the porous lava and basaltic mantle that covers, like a great sponge, much of the region. Numerous springs issuing from the lava and basaltic formations contribute to the effluent nature of these drainage-ways. Because of geological conditions in the region, destructive floods are rare. The larger floods are due to run-off from spring rainstorms augmented by accelerated snow melt. In about forty percent of the years, no significant rain floods occurred.

Section 6-1: Stream Gaging Stations.

6-1.1 Stations on the Metolius and Deschutes Rivers. Records are available for discharge of the Metolius and Deschutes Rivers for stations adjacent to the reservation more or less continuously since the early 1900's. Compilations of stream runoff appearing in U.S. Geological Survey Water-Supply Papers, and in Water Resources of Oregon Bulletins, appear in appendices of this report.

6-1.2 Stations on Streams Flowing Across the Reservation. Records are available for discharge of the Warm Springs River, Shitike Creek, Mill Creek, and Whitewater Creek intermittently since the early 1900's. In addition, miscellaneous discharge measurements have been taken on these and other creeks during this time. Discharge data for these creeks appear in the U. S. Geological Survey Water-Supply Papers, and in Water Resources of Oregon Bulletins.

6-1.3 More data appear for the Warm Springs River and for Shitike Creek than for other streams flowing on the reservation. In general, continuous data appear only for stations on the lower reaches of the streams. Little concurrent data for upstream stations exist to accurately estimate flow ratios at different stream stations.

6-1.4 Tabulation of Gaging Stations. Appendices VI-A through VI-H contain compilations showing average monthly run-off in acre-feet per year and average monthly discharge in cubic feet per second for each month of each year that records are available. Appendix VI-F contains a compilation of all miscellaneous records available for streams flowing across the reservation. Appendix VI-G contains a compilation summary of data for the Metolius and Deschutes River at stations adjacent to the reservation.

Section 6-2: Watershed and Drainage.

6-2.1 Deschutes River. The Deschutes River has its headwaters near the summit of the Cascade Range and forms the eastern boundary of the reservation as it flows northward to the Columbia River. The total drainage area to the river comprises about 10,500 square miles. Two main tributaries to the Deschutes are the Metolius and Crooked Rivers. The most important of the lesser streams tributary to the Deschutes are the Warm Springs River and the White River. Both head in the Cascade Range. Lands through which the Deschutes River flows are generally deeply cut and eroded.

6-2.2 The rocks of the lands cut by the Deschutes River are volcanic in origin and are usually very porous. Numerous springs along its course contribute to its remarkably steady flow. Upstream from the reservation the Deschutes River flows in a precipitous canyon cut in Columbia River basalt, in more recent overlying flows, and fragmental volcanic beds. Adjacent to the reservation the river has exposed the John Day tuffs and clays, and also lavas and tuffs of the still older Clarno formation.

6-2.3 The porous geological formations through which the Deschutes River flows act as underground reservoirs regulating run-off from the snow melt and precipitation of the drainage basin. At the mouth of the river the maximum recorded discharge is only six times the minimum recorded. N. C. Grover (22, p.12) attributes the sustained flow entirely to cellular lava which receives and holds flood waters which would otherwise flow directly down the stream bed. It is concluded that timber stands on the slope of the Cascades have little effect toward stream regulation.

6-2.4 The Deschutes River is an effluent stream of uniform temperature. At Mecca the average yearly run-off is about three and one-half million acre-feet. The minimum average monthly run-off is sixty-three percent of the maximum average monthly run-off. Adjacent to the reservation the Deschutes flows on an average gradient of about thirteen feet per mile. Although the winter temperatures are low, ice does not effect the flow to any extent. This is due to the warm effluent waters that continue flowing into the river during the winter months.

6-2.5 Metolius River. The Metolius River rises on the eastern slopes of the Cascade Mountains, flows northward to form the south boundary of the reservation. It then flows generally eastward to its junction with the Deschutes River. Throughout its course adjacent to the reservation, the Metolius runs in a deep canyon at an average gradient of about thirty-five feet per mile. Like the Deschutes, the Metolius is derived largely from springs and is well maintained throughout the year. The water is chemically pure, it is clear and practically free from drift.

6-2.6 Average yearly run-off of the Metolius adjacent to the reservation is more than 1,000,000 acre-feet. The minimum average monthly run-off occurs in the late fall and is eighty-three percent of the maximum average monthly run-off which occurs in early summer.

6-2.7 Warm Springs River. The Warm Springs River is the largest stream wholly within the reservation. It has its source in the Cascade Mountains and flows in a south and easterly direction for a distance of about forty-five miles to its confluence with the Deschutes River. The drainage area is about 550 square miles, sixty percent of which is timbered land. The river drains almost all of the northern half of the reservation. Drainage of the eastern and northern slopes of the Mutton Mountains is direct into the Deschutes River.

6-2.8 The topography of the upper reaches of the river is very rough, and is covered with timber and heavy underbrush. The gradient above Schoolie Pasture is more than 100 feet per mile. Below Schoolie Pasture the gradient averages about forty feet per mile. The last few miles of the river have a gradient of about fifteen feet per mile.

6-2.9 Immediately below Schoolie Pasture the river is joined by the South Fork and flows through hilly country. About two miles east of Hehe Butte the river begins to enter a deep canyon and is soon joined by Badger Creek. The canyon becomes deeper downstream, forming a five hundred foot deep depression between Mill Creek Flat and the Island. The Warm Springs River is then joined at the south end of the Island by Mill Creek and within another two miles by Beaver Creek. Below Beaver Creek, Warm Springs River is eroded to a depth of about eight hundred feet below the adjacent bench lands. The edge of the canyon is formed by a high rim of basaltic lava rock. The steep sides are formed as boulders are eroded or broken off from the rim and fall to the valley below. As the canyon becomes deeper in the lower reaches of the Warm Springs River, it has been widened to such an extent and the canyon walls cut up by secondary erosion that the canyon-like character becomes lost in the many ravines, hills, and benches.

6-2.10 The Warm Springs River displays some of the characteristics of the sustained flow that do the Deschutes and Metolius Rivers. Destructive floods are unusual. The river is effluent. The ratio of discharge between run-off at the bridge between the Agency and Simnasho to that of the run-off near the former Hehe Mill is about two and one-half to one. Average annual run-off at the mouth of the river is over 330,000 acre-feet. The minimum monthly average run-off occurs in September or October and is about forty-two percent of the maximum average run-off which occurs in May. Water flowing in the Warm Springs River is clear, free from undesirable chemicals, and rarely freezes in the winter.

6-2.11 Badger Creek. Badger Creek has its headwaters near Blue Lake. It flows easterly between Fort Butte and Badger Butte and is then joined by both forks of Cedar Creek. The entire upper watershed is covered by an excellent growth of timber. Badger Creek flows around the northern end of Sidwalder Butte, and crosses the northerly portion of Mill Creek Flat at a comparatively flat gradient. Except for the last half mile of its course above its confluence with the Warm Springs River, Badger Creek does not flow in a canyon.

6-2.12 Continuous discharge data are not available for Badger Creek. Minimum discharge of Badger Creek is listed in the Range Report of 1937 (79, p.8) as being probably sixteen cubic feet per second. From miscellaneous measurements taken on this stream and reported in Appendix VI-F, it would appear that average minimum discharge is frequently less than ten cubic feet per second. A discharge of 7.2 cubic feet per second was reported September 5, 1915. The creek has a relatively uniform flow throughout the year, being fed at its headwaters by springs.

6-2.13 Mill Creek. Mill Creek has its source in a chain of lakes on the eastern slope of the Cascade Range. These lakes are Olallie Lake, Long Lake, Dark Lake, Island Lake, and Trout Lake. Trout Lake is the lowest of the chain of lakes. The creek flows for a distance of about twenty-three miles to form the third tributary of the Warm Springs River. From the outlet of Trout Lake to its confluence near the southern tip of the Island, Mill Creek has an average gradient of one hundred feet per mile. During the first ten miles downstream from Trout Lake, the drainage is eroded to a depth exceeding seven hundred feet. About two miles west of the Old Mill Ranger Station the creek emerges from the deeply cut canyon and flows in a shallow stream bed. At a point about four miles from its mouth, Mill Creek is joined by Boulder Creek and immediately descends into a steep box canyon.

6-2.14 Mill Creek receives most of its water from snow melt on Olallie Butte, though it is also fed by springs along its banks. Run-off is generally well sustained throughout the year. The great underground water storage capacity of the cellular volcanic formations at the upper reaches of the Cascades appears to contribute to springs that continuously flow into Mill Creek. Concurrent observations at the mouth of Olallie Lake (the upper lake of the chain of five lakes) and at the Old Mill Ranger Station indicate discharge at the lower reaches of Mill Creek to be about forty-five cubic feet per second when discharge from outlet of Olallie Lake ceases. The minimum recorded discharge for Mill Creek below the Old Mill Ranger Station is 42.2 cubic feet per second, occuring during the month of September. Only miscellaneous measurements are available for the lower reaches of Mill Creek. Discharge data indicate the stream to be effluent.

6-2.15 Middle and Boulder Creek. Middle Creek is tributary to Boulder Creek, which in turn is tributary to Mill Creek. Each of these creeks is supplied primarily by snow melt and frequently ceases to flow during the late summer and fall. Only miscellaneous measurements are available for these two streams.

6-2.16 Beaver Creek. Beaver Creek is the fourth tributary of the Warm Springs River. It has its source about three miles north of the present boundary of the reservation. The creek flows in a south and easterly direction a distance of about twenty miles. During the first seven miles the creek is fed by numerous sustained springs and by drainage from Butte Creek. During the last fifteen miles of its course the channel of Beaver Creek is deeply eroded. About seven miles from its confluence with the Warm Springs River, Beaver Creek is joined by Coyote Creek. As Beaver Creek flows between the Island and Schoolie Flat, it more or less parallels the Warm Springs River, flowing in a deeply cut stream bed approximately two miles to the northeast. The average gradient is about forty feet per mile.

6-2.17 Although the drainage area of Beaver Creek is comparatively small, the flow is fairly steady. Only miscellaneous measurements are available for Beaver Creek. Average discharge is listed by the Range Report of 1937 (79, p.10) as being fifty-seven cubic feet per second. Discharge less than twenty cubic feet per second has been observed. A comparison of concurrent miscellaneous measurements from Mill Creek indicates that run-off from Beaver Creek is about ninety percent that of Mill Creek.

6-2.18 Butte Creek and Coyote Creek. Both Butte Creek and Coyote Creek discharge into Beaver Creek. No discharge data exist for these two streams. Each are frequently dry during the latter part of the summer or early fall. Coyote Creek is probably the stronger stream of the two, being served by a larger drainage area, and receiving considerable effluent seepage from the watershed lying to the east.

6-2.19 Shitike Creek. Shitike Creek, a tributary to the Deschutes River, has its source in Harvey Lake and in the adjacent watershed lying south and west of the lake. The creek flows nearly due east across the reservation for a distance of about thirty miles. Drainage area is limited to lands lying within two or three miles on either side of the creek. Tenino Creek is the only tributary of any importance, it being an intermittent stream that is usually dry during summer months.

6-2.20 Shitike Creek flows in a deeply eroded channel throughout most of its length. The stream bed in the vicinity of Peters Pasture flows out on a broad valley floor that is about three-fourths of a mile wide and two miles in length. The gradient here is relatively flat. Leaving Peters Pasture, Shitike Creek enters a steep and deeply cut canyon, flowing on a gradient of about one hundred feet per mile. The canyon becomes more deeply eroded in the lower reaches of the creek. About five miles from its confluence with the Deschutes River, the valley floor of the Shitike Creek widens and the gradient reduces to about fifty feet per mile.

6-2.21 Shitike Creek is a well sustained stream, receiving much of its water from the ground water in the high slopes of the Cascades. The creek has a minimum monthly average run-off equal to forty-three percent of its maximum monthly average run-off. Average minimum monthly discharge of 60.8 cubic feet per second occurs in September, although a minimum daily flow of thirty-two cubic feet per second has been observed in both August and September. With the exception of the Warm Springs River, no other stream on the reservation has been investigated as extensively. More or less continuous records exist for Shitike Creek near the Agency between 1911 and 1928. Only miscellaneous data exist for upstream stations. The stream is apparently effluent.

6-2.22 Seekseequa Creek. Seekseequa Creek flows easterly for a distance of about fifteen miles across the southeastern portion of the reservation, and is a tributary to the Deschutes River. The drainage begins on the eastern slope of Shitike Butte. About three miles east of Twin Buttes the stream bed descends rapidly into a deeply cut canyon. The main stream of the creek is joined by a south fork about six miles upstream from the mouth. The canyon of Seekseequa Creek is about six hundred feet deep, the canyon walls being severely eroded and cut by deep ravines.

6-2.23 The headwaters of Seekseequa Creek are apparently too far removed from the Cascade summit to tap these ground waters of higher elevation. Snow melt and springs from lower elevations are the main source of its water. As a result, the creek carries only a limited amount of water. Only one miscellaneous measurement has been obtained on Seekseequa Creek, it being a measured discharge of two cubic feet per second during June 8, 1912. The minimum monthly average discharge probably is considerably smaller than this one observation would indicate. During the late summer of 1959 the discharge near its mouth appeared to be less than one cubic foot per second.

6-2.24 Whitewater River. Whitewater River has its headwaters in two forks on the north and east slopes of Mount Jefferson. It flows for a distance of about fourteen miles in the southwestern portion of the reservation, discharging into the Metolius River. The north fork receives its water from melting snow and effluent seepage from the north face of Mount Jefferson. The south fork, known as Milk Creek, receives water from the melting ice of a glacier on the east face of the mountain. Whitewater River flows in a canyon eroded to depths exceeding 1200 feet. The deeper depths occur at the upstream reaches of the river. The canyon walls are very steep, and in general have not been subject to gullying and secondary erosion as has the canyon of the lower Warm Springs River or lower Shitike Creek. Near the mouth of the south fork, or Milk Creek, the canyon floor widens. Here are small meadows and swamps, similar to those occurring at Peters Pasture. Elsewhere, the rivers flows swiftly along a narrow stream bed bounded on either side by sheer rock walls.

6-2.25 The Whitewater River flows on an average gradient of slightly less than two hundred feet per mile. During the last eight miles of its course the gradient is one hundred and sixty feet per mile. Because of its steep descent, the river has considerable promise for power development.

6-2.26 Available run-off data for Whitewater River are limited to that obtained near its mouth between 1911 and 1914. Minimum discharge of ninety-eight cubic feet per second as reported in the Range Report of 1937 (79, p.14) does not appear to be consistent with stream discharge data reported by U.S. Geological Survey Water-Supply Papers. Helland, in a hydrological report of 1944 that is submitted in Appendix XII-E.2, reported a minimum discharge of forty-one cubic feet per second occurring on December 30, 1911. Since the time of Helland's report, hydrological data published by the U. S. Geological Survey have been revised to show a minimum discharge of thirty cubic feet per second occurring on December 28, 1913. The short records that are available indicate minimum monthly average discharge of fifty-eight cubic feet per second occurring in October.

6-2.27 Jefferson Creek. Jefferson Creek forms a part of the southern boundary of the reservation. It has its source near the summit of the Cascade Range between Bald Peter Mountain and Mount Jefferson. The Creek flows for a distance of about twelve miles in an east and southerly direction to empty into the Metolius River at the southwest corner of the reservation.

6-2.28 Jefferson Creek flows on a gradient that averages about three hundred feet per mile. The lower six miles flows in a deeply eroded canyon that somewhat levels and widens out near its mouth at the Metolius River.

6-2.29 Melting snow and springs on Mount Jefferson are the source of water for Jefferson Creek. There are no discharge measurements published in U. S. Geological Water-Supply Papers that indicate the run-off of this drainage. Helland, see Appendix XII-E.2, reported a measurement by the Agency office in June 9, 1912 indicating a discharge of 161 cubic feet per second. The point of discharge was not recorded. On the same date, U. S. Geological Survey records show a discharge of 239 cubic feet per second for the Whitewater River near its mouth. This would indicate that run-off of Jefferson Creek may approximate sixty-five percent of the run-off of the Whitewater River.

Section 6-3: Water Quality

6-3.1 Debris and Detrital Material. Rivers bounding the reservation and the larger streams flowing across the reservation have as their source snow melt and effluent seepage from ground water. Flood waters which come from snow melt in the spring and early summer are generally free from detrital material. The channel beds of these drainages are usually underlain with rock which allows the flood waters to remain clear as they flow in their natural course. Destructive floods which would carry an unordinarily large amount of suspended material are rare.

6-3.2 Water Temperature. Although the winter temperatures are low, ice does not generally affect flow of the streams, for the winter flow is derived largely from springs or effluent seepage. It is probable that the formation of ice will never be a disturbing factor in the operation of power plants in this area where air temperatures in winter are often well below freezing.

6-3.3 Records are available for water temperature of the Warm Springs River for years 1950 to 1953 inclusive. The recording station was near the former Hehe Mill. A compilation of these records which appears in Appendix VI-I indicates average minimum water temperatures of 36° Fahrenheit occurring during December, January, or February. During the four years that observations were taken, water temperature reached the freezing point on six different days. In this four year period the maximum recorded water temperature was 59° Fahrenheit, with an average maximum for the month of July of 57° Fahrenheit.

6-3.4 Dissolved Solids. The Deschutes and Metolius Rivers, and the streams flowing across the reservation drain a region in which the exposed rocks are Tertiary lavas, tuffs, and basalts. Effluent seepage into these drainages comes from the same type formations. The mineral matter carried in solution is made up largely of salts of sodium, chiefly bicarbonate, which have been reached directly from the disintegrating rock material.

6-3.5 Waters of the Deschutes River and its tributaries are soft, yet contain sufficient dissolved minerals to be palatable. The water appears to be satisfactory for irrigation and industrial use, and with precautions would be ideal for domestic consumption. There are apparently no chemical analysis data available for the surface waters flowing across the reservation. The extent of dissolved solids and other suspended material in the larger effluent streams such as the Warm Springs River and Shitike Creek probably approximates that found in the Deschutes River. The glacier-fed Whitewater River and the very swift Jefferson Creek may be quite similar in dissolved solids content, but may contain a greater amount of suspended matter.

6-3.6 U. S. Geological Water-Supply Papers (78, no. 1293, p.328, no. 1430 p.196) report analysis of dissolved solids in the Deschutes River at Bend and near its confluence with the Columbia at Moody. At the upstream station the waters contained about seventy parts per million dissolved solids. Downstream near Moody, the dissolved solids were reported to be ninety parts per million. The solids were mostly in the form of carbonates. The analysis reported at either station complies with quality tolerances for industrial process waters by the Committee on Quality Tolerances for Industrial Uses (11, p.531).

6-3.7 A water quality inventory published by Oregon State Water Resources Board (43, no.2, pp.29-31) lists bibliographical tabulations for physical, bacteriological, chemical and mineral tests for waters in Metolius and Deschutes Rivers. No data are given for streams flowing in the reservation.

6-3.8 Bacteriological Quality. Hydrology, geology, and topography prevail for ideal sanitation of the streams originating and flowing within the reservation. Headwaters of all these streams have their source at high elevations in remote area. Except during periods of peak discharge due to spring snow melt, these streams obtain their waters from the numerous springs adjacent to their course. A thick soil and rock mantle overlies the water-table to offer protection against contamination of the ground waters which feed the streams.

6-3.9 These surface waters often become polluted from human and animal waste as they flow adjacent to farmsteads in the lower elevations. Such surface water then becomes safe for human consumption only if preceded biological treatment. The surface water drawn from lower Shitike Creek for domestic consumption at the Agency is disinfected by chlorination. Untreated surface waters drawn from the Mill Creek Irrigation Unit and used for household consumption have been found by the Sanitation Staff of the Division of Indian Health to be invariably unsatisfactory. The quality of these shallow wells which draw upon surface waters is more fully discussed in Chapter IX.

6-3.10 Fish and Recreation. The Metolius and the Warm Springs Rivers are the principal salmon supporting tributaries of the Deschutes River. These streams support runs of spring Chinook salmon and steelhead trout. Topography and sustained flow patterns of the streams bounding and flowing across the reservation contribute to recreational and fishing potential.

Section 6-4: Summary.

6-4.1 Records. Continuous records for stream discharge during the past thirty-five years are available for gaging station on the Metolius and Deschutes Rivers. For these rivers, records are available for water quality. Only short time discharge records are available for streams originating and flowing across the reservation. Some miscellaneous discharge data are available. Little data are available for gaging stations in the upper reaches of the reservation streams. No data exist for Jefferson Creek, and only meager measurements are available for Whitewater River.

6-4.2 Discharge Patterns. Both the Metolius and Deschutes Rivers have remarkably sustained flow. The larger spring-fed streams on the reservation are comparatively steady in their discharge pattern. Most of the deeply eroded stream beds on the reservation appear to be effluent. All streams and rivers in this area show flood stages in the spring from snow melt. These floods are rarely destructive. The waters are generally free from detrital material and ice.

6-4.3 Topography and Gradient. Most of the streams on the reservation flow in deeply cut canyons at a comparatively uniform and steep gradient. Sustained flow patterns in such surroundings suggest hydro-electric development by stream diversion into canals and conduits. These streams flow in picturesque surroundings, and have great fishing and recreational value.

Section 6-5: Recommendations.

6-5.1 Discharge Data. Additional stream discharge data are needed on the streams originating on the reservation. Run-off at the higher elevations is needed to determine feasibility of power and irrigation development. It is suggested that a stream measurement program be initiated that would supplement data now available. Such a program should be supervised by the Hydrology Division of the U. S. Geological Survey, and fullfill requirements for close analysis of power and irrigation development outlined in Chapters XI and XII.

6-5.2 Utilization. The sustained flow and excellent quality of waters from the streams of the reservation suggest several methods of utilization. The surface waters if protected from pollution or given adequate biological treatment offer satisfactory sources of domestic or rural supply water. Sustained flow during summer months and freedom from undesirable dissolved salts cause the waters to be ideal for irrigation. Because the streams show a remarkably uniform flow that is free from drift or ice throughout the year, and because their natural course follows a uniformily steep gradient, water-power development using canals or conduits to develop head is indicated. Enterprise, such as commercial fish hatcheries, requiring moderate amounts of surface water of uniform and high quality would appear to be attracted.

CHAPTER VII

GEOLOGICAL FACTORS INFLUENCING OCCURRENCE OF WATER WITHIN THE RESERVATION

The topography is severely eroded, exposing five geologic formations. Where the deeply cut canyons abut against the higher bench lands, the water-table is depressed far below the surface of the plateaus. Permeability of the volcanic materials varies. The tuffs and ash of the older formations tend to be dense and fine-grained, unfractured, and to be impermeable. The more recent volcanic extrusions appear more permeable, but are often located above the water-table. These are either basaltic, andesitic, or rhyolitic composition, frequently interbedded with gravels or sediments, or characterized by fractures and vesicles at their upper boundaries. The reservation lies in regions of scant rainfall. Ground water is frequently difficult to obtain by wells.

Section 7-1: Stratigraphy.

7-1.1 The Clarno Formation. The Clarno formation was named from rocks found in the vicinity of the Clarno Ferry along the lower part of the John Day River. It is a Tertiary formation, and the oldest that outcrops on the reservation. Clarno deposits are a heterogeneous mixture of gravels, sands, clays, agglomerates, breccias, tuffs and ashes. The tuffs are partly weathered into clay, and the lavas are often dense and compact. The tuffs are yellow, cream-colored, grey, green or red. They are invariably fine-grained and highly consolidated.

7-1.2 In early Clarno time streams carried older rocks as well as sands and clays to deposit them thinly over much of the area. Later, a period of volcanism ejected clastics in the form of agglomerates, breccias, tuffs and ashes. This material was transported through the air, although some was probably carried by water and deposited by streams or lakes. The first volcanism was predominated by basaltic rocks, later to be followed with rhyolite and occassionally with andesite.

7-1.3 In addition to pyroclastics, the Clarno formation contains many lava flows, some acid, some basic. These flows were usually rhyolitic, although andesites and basalts were common. The many rock types produce a great variety to the Clarno formation. During the late Eocene time, the Clarno formation was locally deformed and eroded to a mature stage.

7-1.4 The Clarno formation is very resistant to erosion, although the massive resistant beds are often interbedded with soft deposits. The Mutton Mountains rising in the northeastern part of the reservation are old Clarno Hills. These mountains are a cubical uplift that has survived the ravages of erosion long after the cover of the John Day tuffs and ashes had been deposited and eroded away. Clarno topography also appears north of Simnasho. Exposed Clarno formations yield large rough inclined surfaces, knobby hills and buttes. Erosion on the alternating layers of resistant lavas and softer sediments create fretted and scalloped edges. The rhyolites form weather resistant protecting domes to the great shielded hills. The rocks are superficially fractured, appear strongly folded and faulted, and in most places weathered and metamorphosed.

7-1.5 The depth of the Clarno is not known. Stearns (53, p.135) estimates it to be at least 1000 feet deep. In many places the Clarno is so deeply covered by younger formations that it is regarded as inaccessible to wells.

7-1.6 Landsliding is common in the Clarno formation. This tendency to slide is common to all formations on the reservation comprised chiefly of consolidated ash and tuff.

7-1.7 The John Day Formation. The John Day formation is volcanic ash and tuff that rests unconformably upon the eroded Clarno. It is composed chiefly of andesitic, dactic and rhyolitic material. The deposits which vary from a few feet to more than two thousand feet in thickness are composed largely of a consolidated and tight deposit of white, yellow, red, or green ash or tuff. The John Day beds were subject to stream and wind erosion during the time of their formation and afterwards. This erosion produced heterogeneity in the formation, localizing the heavier water-borne sediments. Baldwin (4, p.81) reports in some places the John Day formation appears to grade into acidic flows, breccias and coarse tuffs that might be easily confused with the underlying Clarno.

7-1.8 The lack of a good bedding indicates that these ashes were wind-borne. The volcanic activity may have been toward the west from what is now the Cascade Range, the ashes being borne by the same westerly winds that prevail today. Newcomb (40, p.4) and Baldwin (4, p.72) suggest this deposition occurred during early Miocene time. The John Day ashes filled all the basinal areas, abutted against and buried many of the Clarno uplifts. Of the ashes which fell on the Clarno, many were soon washed away by streams from the hills into the depressions. The great alluvial basin received both wind-blown tuffs from nearby volcanoes as well as flood-plain sediments and deposits from erosion of the older Clarno formation. During this period the John Day formation in the lowlands was leveled and eroded by numerous wandering streams into a flat plain lying at the foot of the surrounding hills composed of the Clarno formation.

7-1.9 Hodge (24, p.10) classifies the John Day formation into three stratigraphic groups. The lower John Day deposits consist of white, yellow or red tuff and ash. At first the ash falls were probably loosely laid and permeable. They did not materially obstruct the drainage. In those regions where they did, the porosity of the ash and tuff permitted water to seep through. This caused oxidation and breakdown of the iron-bearing minerals, giving a yellow or reddish coloration to the formation. The middle John Day is composed of white and often green colored tuff containing nodules and fossils. Rhyolite flows are common near the top of the middle John Day deposits. The upper John Day is composed of ash or tuffs of a white or buff color. Some gravels occur at the top of the upper layer. This upper surface was sometimes baked red by their burial beneath the hot and overlying basalt that followed.

7-1.10 The John Day is a weak formation, showing a tendency to slip on steep slopes and to landslide. It is displaced in many places by what appear to be faults. Hodge (24, p.51) reports this faulting and folding of the John Day is due to gravity and not due to orogenic compression. This gravitational folding of the John Day formation began immediately after its deposition and has continued to this day. This causes local deposits of the John Day formation to appear from beneath younger formations. Water flowing over the rim-rocks, or springs emerging at the contact between the rock and tuff soak the John Day, causing it to slip and landslide. The unsupported rim-rock falls to the valley floor making conditions ideal for renewed landslides.

7-1.11 Today the John Day formation can be seen preserved in cliff walls beneath its protecting cover of basalt. The terrain lying below 1800 to 2200 feet elevation in the drainage of Shitike Creek, Tenino Creek, Warm Springs River, and Deschutes River exposes beds of the John Day formation. The John Day beds can be seen as far north as Skookum Creek northeast of the Mutton Mountains, and in the vicinity of Simnasho.

7-1.12 John Day ashes and tuffs have always been easily removed by erosion when not overlain by a more resistant formation. It blows away so easily it does not form a soil except in basins. When not covered, it usually takes the form of steep gullied slopes, pinnacles, or badlands.

7-1.13 The John Day formation is preserved at the lower elevation where established stream beds have eroded through the John Day to hard rock. Basins such as Shitike Creek and Warm Springs River are guarded by a base-level of hard rock through which the streams can but slowly cut.

7-1.14 The Columbia River Basalt. The Columbia River Basalt formation is composed of basaltic material that rests conformably upon the John Day formation. In places where the John Day had been eroded the basalt lava lies directly upon the Clarno. The formation is characterized by prominent flat surfaces and rim-rocks. Alcoves and box canyons are frequently eroded into its edge by springs which undercut its foundation.

7-1.15 Basaltic flows that comprise the formation are reported by Hodge (24, p.14) to have probably originated from thousands of short-lived small vents and fissures. The individual lava flows appear to have been only a few miles long, quite narrow, and from ten to two hundred feet in thickness. Columbia River Basalt is exposed today on the North Block and South Block, two plateaus lying between the Mutton Mountains and the Deschutes River. A small area of the formation is exposed along the east side of a small plateau west of Mecca, and along the side wall of the plateau southeast of the Agency. Some volcanic activity that produced the John Day ashes and tuffs was probably concurrent with the lava flows of the Columbia River Basalt. This is indicated by the interbeds of volcanic ash that occur in the lower basalt. There appears no distinct time break between the two periods of volcanic activity.

7-1.16 The Columbia River Basalt is further identified by the large hexagonal prisms that now stand vertically side by side due to cooling and contraction. The columns, which are big at the bottom and become smaller toward the top, tend to fracture and break off at right angles to their length. Fractures at the upper portions of the flow are frequent and show an irregular surface. Breaks towards the base of the columns are smooth and widely spaced. The top of each flow is frequently covered by a vesicular lava which weathers and breaks down to a red soil.

7-1.17 The Columbis River Basalt is resistant to erosion except where undercaved. Canyons cut into the formation are usually V-shaped. The dark brown weathered surfaces extend inward only a few inches. The interior of the basalts is a lustrous black, and has a fine and even grain.

7-1.18 The Dalles-Madras-Deschutes Formation. Following the localized but widespread lava flows of the Columbia River Basalt, extensive volcanic activity began in the area now known as the Cascade Range. Various names have been given to the formation resulting from this renewed volcanism. The Dalles formation was the name used by Rev. Thomas Condon, an early minister, who observed the deposit near his home at The Dalles. What appeared to be the same deposits within the broad Deschutes Valley were first described by Russell (52, p.90) who suggested the name Deschutes sand. Because the formation contained lava beds, diatomite and many other deposits it was later named the Deschutes formation by Williams (87) who conducted geology studies of the Pelton Dam Site in 1924. Hodge (24, p.23) gave the name Madras formation to similar deposits found in the Madras quadrangle, but later concluded that they were equivalent to the Dalles formation. He proposed that the name Dalles formation be extended southward to the Madras area.

7-1.19 The Madras formation of Hodge is considered by some (4, p.74) to be younger than the early Pliocene Dalles formation named by Condon. Both are a result of alluviation into the Deschutes Valley that apparently had its source from what is now the Cascade Range. The formation that is referred to as the Dalles, the Madras, or the Deschutes is hereinafter in this report termed the Dalles formation.

7-1.20 The formation is of a variable composition consisting of lava flows and water-spread materials. These fluvial beds occur interbedded with the basaltic lava flows, infrequently at the base and more frequently at the top. Hodge (24, p.24) reports that about ninety percent of the Dalles formation is of volcanic origin. Where it lies combined with debris from older formations it becomes difficult to identify.

7-1.21 Layers of lava interbedded with ash, sand and gravel lenses were deposited unconformably upon the John Day and Columbia River Basalt in the leveled area. The sediments consist of agglomerative mud flows, gravels, sands, ash and tuffs. The mud flows, agglomerates, ash and tuffs are consolidated, while the other materials are often loosely laid.

7-1.22 The lavas of the formation are reported by Hodge (24, p.23) to vary from fifteen to two hundred feet and to average seventy-five feet in thickness. Stearns (53, p.137) reports exposed thickness of the formation termed Deschutes to in places exceed one thousand feet. The basaltic lavas were apparently hot and fluid, as they flowed out for great distances in thin sheets, covering all but the higher Clarno hills in the eastern part of the reservation. Towards the source of the volcanic activity in the Cascades, the lava flow is thicker and appears as a steeply inclined flow. On the basins farther from the range, the lavas became more horizontal. As the depressions became filled with the Dalles lavas, the inclination away from the Cascades decreased until the beds attained a more or less uniform gradient from west to east of about one degree. In all cases they rest undeformed, sloping away from the Cascades.

7-1.23 The basalt members of Dalles formation, referred to as the Deschutes by Williams and Stearns (53, p.137), have been for convenience designated into two basic deposits. The uppermost basalt flows are termed the rim-rock basalt, the lowest intercalated basalt member is known as the Pelton basalt. Stearns describes the Pelton and rim-rock basalts:

> "Because of the importance of this bed as a water bearer and its critical relation to the dam sites in the region, it has been named, for convenience, the Pelton basalt member (this name has been used in private reports by Ira A. Williams), after the old railroad station. It has a known thickness of over 150 feet.........It also extends up the Metolius River for at least two miles and then passes under sedimentary beds. Undoubtedly it is the most extensive and the thickest of all the interstratified basalt members of the Deschutes (Dalles) formation. The Pelton basalt usually consists of several beds that were laid down in rapid succession, and it is not unlikely that they were all poured out during a single eruption............"
>
> "The sedimentary beds are capped in about one-half of the middle Deschutes River basin by beds of basalt. In the rest of the area, this basalt cover has been removed by erosion. It is very prominent because it forms the rim rocks to the canyons and underlies at shallow depths much of the agricultural area. Its thickness varies according to the distance from its source, and most, if not all, of its sources are still visible as cones on the plain ....Because this basalt is conspicuous as the protective, resistant rock of the region it is here referred to as the rim-rock basalt, a term in common use among the local people......Its lava flows were spread out evenly upon the plain, and if it were not for the great canyon carved through them no one would suspect that issuing cones had long been silent. However, not only has a 1,000 foot canyon been carved since erruption, but also a second canyon nearly as deep in the younger intracanyon basalt....."

7-1.24 Streams apparently cut into the Dalles sediment beds easily. Beneath the rim-rock the fluvial sediments slump away, the rim-rock breaks off to form the U-shaped canyons.

7-1.25 The Cascan Formation. Following the Dalles volcanism, quieter activity continued from the vicinity now known as the Cascade Range. The resulting formation designated by Hodge as the Cascan formation is composed mainly of andesitic lava flows, agglomerates, tuffs, and ash. Some basalt, rhyolite and dacite also occur in the formation. The Cascan formation lies on the undeformed Dalles formation at the western portion of the reservation. It is the uppermost geologic formation found on the reservation.

7-1.26 The lavas of Cascan time flowed over the gentle surfaces of the Dalles formation, filling pre-existing drainage. Boundaries of the Cascan formation do not extend as far east from the Cascades as do the Dalles flows. Like the Dalles formation most of the volcanoes were in the central zone of the Cascade Mountains. Occasionally, isolated vents such as Round Butte, Hehe Butte, Sidwalder Butte, and Shitike Butte were far to either side of the range.

7-1.27 The Intra-canyon Formation. After canyons had again been established through the Cascan formation, forming the drainage evident today, local volcanism and venting was renewed. Although the basaltic flows buried some of the older topography south of the reservation, the Intra-canyon flows on the reservation were mainly confined to lava flowing into the present Metolius River drainage and into the present Deschutes River drainage near the vicinity of the proposed Round Butte Dam. The name Intra-canyon formation has been given to this deposit.

7-1.28 Vents adjacent to the Metolius River in Township 11 South, Ranges 11 and 12 East flowed into the canyon and filled it in places to an elevation of nearly 2,400 feet, or approximately within three hundred feet of the top of the eastern Metolius bench. The lava apparently came in rapid and successive flows. After the Intra-canyon flows, the old stream bed was re-established to approximately its former position and depth. The streams have cut through the Intra-canyon lavas, leaving masses of lava on either or both sides. These lavas have flat tops and form discontinuous little benches that occur in long strips on one or both sides of the canyons. These are exposed today along the north face of Metolius canyon near Fly Creek and Spring Creek, and along the west face of the Deschutes Canyon west of Round Butte.

7-1.29 Stearns (53, pp.145, 148) describes the Intra-canyon basalt:

> "The age of the Intra-canyon basalt is unknown, but from its stratigraphic position it is thought to be late Pleistocene or Recent. It is little weathered, and all the original surface features of the flow are preserved, except the thin glassy crust a fraction of an inch thick which has flaked off and lies in the depressions on the surface. The immense canyons cut into it give an impression of great antiquity, yet the jointed and fractured lava yields readily to the swift rivers of the region."
>
> "The jointing and bedding vary from outcrop to outcrop. On the west wall of the Deschutes Canyon in Section 15, Township 11 South, Range 12 East, the Intra-canyon basalt consists of twenty-three distinct layers. Such variations in structure indicate that the flow at no time or place was a great moving river of lava several hundred feet thick. The distribution of lava to such distances as are indicated by the length of this flow is

> accomplished by means of a great subway system of tubes connecting the source with the end of the flow. The tubes or tunnels through which the lava moves are formed within the flow itself by the crusting over of a lava river. Once they are formed the lava is able to travel long distances underground without any great loss of heat, for radiation through the crust of a lava flow is very slow."

7-1.30 Alluvium. Establishment of stream patterns on the reservation has caused alluvial deposits to be formed at lower elevations. These fans and lenses often have a position and permeability favorable for yielding ground water. In older times, the water courses cutting into the soft and impermeable John Day formation were later filled with the more permeable basaltic flows. The more recent cutting first eroded narrow gullies through the Cascan lavas, then encountered the softer Dalles and John Day beds. The rim-rock and heavier Dalles sediments removed from the higher elevations were deposited in alluvial fans, mixed with tuffs and ash to form more or less permeable beds. In the northeast part of the reservation, detrital off the old Clarno uplifts has been carried by streams to lower elevations, where they now rest in a matrix of tuff and ash.

Section 7-2: Rock Texture and Structure.

7-2.1 Igneous Rocks of the Reservation. The rocks found on the reservation are of volcanic origin, being andesites, rhyolites, and basalts. The basalts are the youngest of the three, and in general display a greater effective permeability to make them important as an aquifer. Andesitic rocks are usually found to be dense, compact, and so impermeable as to yield little water. Rhyolites are usually slightly more permeable than the andesites, but seldom are capable of yielding as much water as do the basalts.

7-2.2 Andesite. Andesite is typically a compact rock. The rock is refractory, often during volcanic eruptions being blown out in fragments. The colors are usually a shade of green, blue, brown or red. The compact varieties often are bluish or green, and tend to weather with a thin light-colored crust. When andesites contain a considerable percentage of ferromagnesian minerals, they are often darker colored, the weathered crust being thicker and markedly rusty in its appearance. Some varieties of andesite are difficult to distinguish from similar fine-grained basalts.

7-2.3 Silica (SiO_2) comprises fifty-five to seventy percent of andesite. The next important constituent is alumina (Al_2O_3) which varies from ten to twenty percent. A striking feature of weathered andesite is the large percentage of lost silica.

7-2.4 Andesite is usually found to be so dense and compact that it is generally regarded as incapable of yielding water in usable amounts. Stearns (53, p.197) describes water in andesite:

> "......In the outcrops observed it is dense, massive and tightly jointed, giving the appearance of relative impermeability.

No wells or springs occur in it, and without further proof of its water-bearing capacity, it is classed as a poor aquifer. Wells in it will probably have small yields, or will be failures."

7-2.5 Rhyolite. Rhyolitic rock is typically a crystalline rock. Rocks of this group are usually found to display subdued shades of red, purple, yellow, and brown. They frequently have a banded or stratified structure, composed of many thin, irregular layers which show variation in color and in texture. Rhyolite contains about seventy-five percent alumina, combined with several other oxides of alkaline earths. These rocks are difficult to fuse, a characteristic which has an important bearing on the forms which the lava assumes upon cooling. The rock is often fragmentally ejected during volcanic activity.

7-2.6 The angular fragments, grains, and dust of rhyolitic lavas blown out of volcanoes during explosive erruptions fell upon adjacent terrain or bodies of water to form beds. These beds were more or less consolidated, sometimes being quite dense, and other times retaining their original unconsolidated condition, and appear as loose gravel, sand or dust.

7-2.7 Rhyolite is generally regarded as being a better aquifer than is andesite. Rhyolitic rock usually presents a marked heterogeneity in its structure, as the rock was often deposited fragmentally. While rhyolitic deposits are found having varying degrees of consolidation, they are usually sufficiently permeable and porous to yield at least moderate amounts of water.

7-2.8 Basalt. Basalt is a grey, dark green, or black rock. Because of abnormally great amounts of oxidized iron present, the rock is sometimes found to have a red color. Silica (SiO_3) forms forty-five to fifty-five percent of the rock; alumina (Al_2O_3) forms ten to twenty percent. Frequently isolated grains or an occassional granular aggregate of green or yellowish-green olivine may be seen, even in the most smooth compact basalt. Basalt weathers with a thick rusty or yellowish-brown crust, which often exfoliates in concentric shells. Owing to ferromagnesian constituents, the rock often assumes a dull and dirty greenish color.

7-2.9 The jointing of the basic basalt is generally more regular than that of the compact and fine-grained acid igneous rocks such as andesite. Rocks of all kinds when subjected to heat will necessarily expand, and contract upon cooling. Contraction of basaltic lava flows results in a rent and fissured deposit. When the molten basalt cools in a horizontal position, the upper and lower surfaces are planes of cooling, this causes a vertically prismatic structure. Of the three types of rocks discussed, basalt is the most easily fused. The rock melts at a low temperature, remains highly fluid as it flows for great distances in thin lava sheets. Basalt is usually the product of lava flows, not usually ejected from a volcano in the form of broken fragments as in the case of the andesites and rhyolites.

7-2.10 Basalt is generally regarded as capable of yielding abundant quantities of water. It is often effectively permeable due to the extensive fracturing occurring during differential cooling of the lava flow. Basaltic lava flows are often highly vesicular, especially at the upper and lower contact. The numerous gas pockets, if interconnected, permit the rock to store and release large amounts of water.

7-2.11 Stearns (53,pp.197-199) describes water in the basalt members of the Dalles (Deschutes) formation occurring in the middle Deschutes Basin:

> "All the basalt members of the Deschutes formation are previous, as is testified by the immense number of springs that issue from them. They are all flows, and because of their similarity of structure and water-bearing characteristics they are discussed together to avoid repetition. Whether water occurs in them in this basin depends entirely upon whether they lie in the zone of saturation or have not been completely drained by the surface streams that expose them."
>
> "The open spaces in this basalt through which water can circulate are enumerated in order of their volume as follows: (1) Large open spaces at the contact of one lava flow with another, or of a lava flow with the underlying formation; (2) interstitial spaces in cinders and as lava formed during deposition; (3) open spaces in joints due to shrinkage of the basalt at the time of cooling; (4) tunnels or caverns formed by the draining away of subterranean rivers of lava during the final phases of eruptions; (5) vesicles and cavities due to the expansion of gases during the cooling of the lava; (6) tree molds resulting from lava surrounding trees and solidifying before the wood has burned away."
>
> "The slaggy contact of one flow with another is the principal passageway for ground water in the basin. These contacts are usually recognized in drilling by a thin layer of easily drilled lava rock, commonly red and lying between two layers of hard blue or black lava. Many of these contacts are visible in the walls of Crooked and Deschutes Canyons, and from some of them issue innumerable springs. The crust of these basalt flows is generally rough and broken, because of the sudden chilling of the lava and subsequent movement of the flow. Inundation by another lava flow never completely fills these irregularities, and the bottom of the overlying flow is usually slaggy for several feet above the contact, owing to the accumulation of doughy masses of lava that cooled from beneath while the flow was in motion......"
>
> "Open slaggy contacts result also at the base of a lava flow where it rests upon sedimentary rocks. The permeability of such contacts is variable, for in some places the lava fits tightly to the underlying bed, while in other places the two may be separated by a cavern large enough to walk through."
>
> "Immense volumes of water can flow through the interstitial spaces in cinders and lava. In this basin, however, cinders and lava are much less common than the regularly jointed basalt,

and hence they play a much less effective part than in many other lava regions. Although not prominent in the zone of saturation, good-sized deposits of both cinders and basalt occur in the zone of aeration, where they doubtless serve as efficient intake beds..."

"Open spaces in the joints due to shrinkage of lava at the time of cooling are so well known that they need no further description.......The distance of gaping of the joints depends chiefly upon the thickness of the flow and the slowness of cooling. Many of the thicker flows are jointed, but the joints are tight and the basalt is not very permeable. The thin flows have more irregular jointing and are much more permeable."

"Tunnels and caverns are formed in basalt by the draining away of subterranean rivers of lava during the final phase of eruptions. They are essential to the spreading out of such extensive sheets of basalt as occur in the Deschutes formation. Their presence is indicated in wells by the dropping of the drill when penetrating lava rock........"

"Vesicles and cavities due to gas expansion in the lava at the time of cooling are very common, especially near the tops of the flows. They are not everywhere connected, and unless the lava is extremely cellular they probably do not allow any great amount of water to circulate. However, the fact that the vesicles in most of the ancient basalts are filled with minerals deposited from percolating waters indicates that some circulation of water takes place even through these small and apparently disconnected cavities."

"Tree molds formed by lava surrounding a tree and solidifying before the wood has completely burned away are roughly circular holes 1 to 3 feet in diameter and as much as 40 feet deep. None were seen in the basin, but this is not surprising because most of the flows are covered with soil. Tree molds were found by the writer in lava flows near Bend. It is an established fact based on observations in the Hawaiian Islands that many tree molds act as conduits for streams of underground water. They occur only locally, hence they are probably the least important water-bearing features in the lava."

"Dikes or feeders to volcanic vents are not exposed in this basin. They must exist, however, for fissure eruptions occurred during the extravasation of the rim-rock basalt. They are impermeable and in places act as barriers to the circulation of ground water. The effect of dikes in the basin could not be ascertained."

"Wells that penetrate the basalt members of the Deschutes formation that lie in the zone of saturation yield ample supplies of water, and for large supplies these beds should be explored."

Section 7-3: Topography.

7-3.1 Drainage and Land Features. With the exception of the Clarno uplifts in the northeastern portion of the reservation, the topography is characterized by bench lands sloping away from the Cascade Range which lies to the west. Established drainage-ways flow generally easterly to discharge into the Deschutes and the Metolius Rivers. The area of greatest precipitation and ground water recharge lies near the summit of the Cascade Range.

7-3.2 The soft tuffs and ash of John Day formation and the sedimentary deposits of the Dalles formation were in many places covered by sheets of basalt. Where the resistant basaltic covering beds have been cut through by streams, canyons with rim-rocks are a conspicuous feature of the topography of the reservation. The canyons expose the mantle of permeable basalt, and the softer but often impermeable materials lying below.

7-3.3 Water-Table. In many places, particularly in the eastern portion of the reservation, the streams have established themselves on a firm bedding at a level of the older and more impermeable formations. This has the effect of lowering the water-table far below the permeable sponge-like basaltic plateau mantle. Other than the perched waters which are seen in numerous places trickling from the canyon walls near the upper contact of the impermeable formations, ground water is often found only at great depths. Here the ground water below the water-table is found usually in formations so tight that yields to wells are often below minimum requirements.

7-3.4 Movement of the more permeable overlying materials to a favorable position below the water-table has been apparently limited to the detrital deposits of streams. Since Clarno time there is but little evidence of orogeny within the reservation on those lands lying east of the toe of the Cascades. What appears to be faulting along the John Day deposits has been attributed by Hodge (24, p.51) to be landsliding. Such deformities are probably too localized and isolated to have great value for aquifer formation.

7-3.5 The impermeable John Day deposits filled the old Clarno basin to great depths. Ancient stream beds, eroded into the John Day formation, may have been filled by the more permeable Columbia River Basalt or by the Dalles sediments. Later, drainage soon cut through the basaltic covering, establishing a drainage in the soft and impermeable John Day tuffs. The heavier basaltic alluvium was deposited at the lower elevations, interbedded with the clays and tuffs of the John Day. Where the more permeable basaltic formations appear to dip down continuously into the John Day formations at a level sufficiently low to become charged with ground water, good producing wells can be expected.

Section 7-4: Occurrence of Water in the Formations.

7-4.1 The Clarno Formation. The Clarno tuffs are so consolidated and tight, their lavas usually so dense and compact, that little opportunity exists for storing or releasing of water. Occasionally closely jointed zones or other localized permeable layers exist to afford small yields to wells. The location and depth of these water-yielding zones are not predictable. It is questionable that such zones are sufficiently continuous to provide sustained flow. Furthermore, the Clarno beds are deep, Stearns (53, p.135) estimating them to be at least one thousand feet in thickness. The Clarno formation is found at most places in the reservation to be overlain so deeply by younger formations as to be practically inaccessible. Only in the vicinity of the Mutton Mountains and in the old Clarno hills north of Simnasho are the Clarno tuffs apparently within practical drilling depths.

7-4.2 The Clarno formation is not regarded as a good water bearer. A few seeps occur from these beds, but wells tapping them usually have but small yields. Abrams (1) describes a 420 foot well drilled into the Clarno formation at Pine Grove, just north of the reservation, that yielded no water. Stearns (53, p.189) reports wells drilled into the acid lavas and tuffs, which appear to be Clarno, to be but meager producers. Any existing water-bearing zones in the Clarno formations are difficult or impossible to locate without extensive text drilling. Fractures, permeable zones, or other conduits for water transportation are localized and occur so infrequently that the Clarno formation is usually regarded as impermeable.

7-4.3 Stearns (53, pp. 192-193) describes the success of wells drilled in the middle Deschutes Basin that tap the Clarno formation:

> "These beds wherever exposed have the appearance of being poor water bearers. Many of the beds consist of fine-grained tuff resembling shale, and others are massive and only sparingly jointed.....In general, it may be said that drilled wells in this formation are successful and yield water ample only for domestic purposes. There seems to be no clearly defined water table, and wells are brought in at various depths according to the depth of a permeable bed or crevice. The pervious (permeable) beds of the formation seem to be filled with water even at shallow depths. Shallow wells are, however, generally unsuccessful in this formation, although a few have been developed from hillside seeps with success. Such wells are mainly catchment basins for the spring run-off from banks of snow and the locally saturated adjacent ground. These wells go dry during the summer.........."

7-4.4 The John Day Formation. Tuffs of the John Day formation are porous, but are fine-grained. Although they absorb water readily, they do not yield it to wells. Newcomb (40, p.5) reports all known attempts to develop wells in the John Day formation have failed to obtain usable amounts of water. Upson (85, p.10) reports beds of the John Day formation in the vicinity of Kah-Ne-Tah Springs on the Warm Springs River as being minutely fractured by superficial weathering, but more compact and presumably solid below the surface. Abrams (1) describes cores sunk into the John Day formation at the re-regulating dam below the Pelton Dam. The formation was found to be virtually water-tight. The holes yielded no water, and water poured into them stood at a sustained level for a long period of time.

The tuffs are described by drillers to swell and expand when wetted. This formation appears to be impermeable, and to act as a tight and often continuous confining layer.

7-4.5 Two conditions appear favorable for tapping usable amounts of water from the John Day formation. The first of these is from alluvial fans or detrital stream deposits which may occur in the tuffs. These more or less permeable lenses may offer a source of ground water if located below the water-table and are sufficiently extensive. Abrams (1) has found water in the John Day formation to be generally limited to the first one hundred feet of the ash and tuff, where the formation often grades into the overlying sediment and rock mantle. Perched water is often limited in its supply, wells tapping such a source often going dry during the later part of prolonged dry periods.

7-4.6 The Columbia River Basalt. Passageways for water in the Columbia River Basalt are generally limited to the slaggy and vesicular contacts between it and other flows or sedimentary deposits, and to fractures induced by differential cooling. Stearns (53, p.197) reports that the slaggy contacts of lava flows are the principal source of ground water, as inundation by overlying flows never completely fills the irregularities adjacent to the contact. The extent of open spaces in the joints due to shrinkage of lava at the time of cooling depends chiefly upon the thickness of the flow and rate of cooling. Many of the thicker flows of the viscous basaltic lavas are jointed, but the joints are tight and the basalt material dense and impermeable. Fracturing is more extensive at the upper surfaces of the flow than in the interior. That the joints at the upper surfaces of the Columbia River Basalt are extensive and allow freedom for movement of water is indicated by the rare occurrence of overland streams entering the box canyons cut into its surface.

7-4.7 Well drillers in the area (1) report the Columbia River Basalt to be very hard to drill, and to generally yield water only in its upper portions. The conclusion is that the Columbia River Basalt is capable of yielding usable amounts of water only from its upper regions, or from poorly defined lines of contact.

7-4.8 The Dalles-Madras-Deschutes Formations. The sedimentary materials of the Dalles (Madras, or Deschutes) formation are mostly fine-grained, although some beds of grit, gravel, and sand are present. Newcomb (40, p.5) reports that lenses of sand or gravel may yield water if the strata are present below the water-table. Because of the fluvial origin of most of the beds, they are in many places cross-bedded. The permeable beds are reported by Stearns (53, p.193) to be non-continuous over large areas.

7-4.9 Most of the Dalles formation immediately underlies or forms the rim-rocks of the tablelands and is cut and drained by the canyons. In such places the formation is high above the water-table. Where these beds lie far enough from the canyons and rest on the impermeable John Day formation, they may contain enough perched ground water to supply a limited amount of water to wells. Stearns (53, p.195) reports an earnest but unwise effort to obtain water by digging in the Dalles formation less than a half a mile from the Deschutes Canyon where the canyon is 750 feet deep. The well, 200 feet deep, was a failure. Much labor could have been saved if the owner had realized that owing to the absence of perched springs from the canyon wall, a well at least 750 feet would have been necessary at this place to obtain water.

7-4.10 Abrams (1) reports wells drilled into the Dalles sediments often to be good producers when the formation lies below the water-table. The sediments of the Dalles formation are found to have a varying structure, some are loose and unconsolidated, but most appear to be cemented. Stearns (53, pp. 188-189) reports a tabulation of wells drilled in the middle Deschutes basin. The deep holes tapping the formations which appear in the well logs to be the Dalles deposits are variable producers, some good, others fair. Stearns concludes that the yield of wells from the sedimentary beds of the Dalles formation is extremely variable, and may in places be insufficient for even domestic use. He reports (53, p.193) the behavior of the Dalles formation in an area lying just off the reservation to the south and east:

> "The beds of sand and gravel in this formation that lie in the zone of saturation and are not consolidated yield supplies of water sufficient for domestic use. However, very few of the great number of springs issue from the sedimentary beds of the Deschutes formation in either the Deschutes or the Crooked Canyon; hence they must be as a whole less permeable than the basalt members of this formation. Because of the fluviatile origin of most of the beds they are in many places cross-bedded and lens-shaped, and permeable beds are not continuous over a very large area."

7-4.11 The basalt members of the Dalles formation are good water producers. The water-bearing characteristics of this formation are discussed in Article 7-2.11.

7-4.12 The Dalles formation because of its great general depth, and because it usually yields at least a moderate amount of water to wells is one of the more important geologic formations. Hodge (23) indicates that the formation is sufficiently thick and favorably located stratigraphically to contain the water-table in much of the area of the reservation. See Appendix VII-B.

7-4.13 The Cascan Formation. The Cascan formation is usually both porous and permeable. It is seldom found below the water-table as it forms the rim-rocks at the top of the deeply cut canyons in this area. Its important function does not appear to be that of an aquifer, but as a highly permeable soil mantle. Its plateau position prevents any possibility of being charged with ground water. The Cascan lavas, lying in an area of low rainfall, receive such small amounts of precipitation that they are nearly always devoid of even surface water. Small quantities of water may be perched within the formation, held there by less permeable lenses. Instances of perched water in the Cascan formation are undoubtedly infrequent, and would not constitute a significant source of ground water.

7-4.14 The Cascan formation is so highly permeable that it presents a serious problem regarding design of surface hydraulic structures such as stock dams, irrigation canals, etc. Seepage losses through such a formation are high unless corrective action is taken.

7-4.15 The Intra-canyon Formation. The Intra-canyon formation is not considered as a significant aquifer for the lands on the reservation. Although the main mass of the formation is porous and permeable, it lies above the water-table exposed as the canyon face along portions of the Metolius and Deschutes Rivers. Because of topography and its stratigraphic location, the formation is devoid of water where it appears on the reservation.

7-4.16 Alluvium. The value of the recent alluvium as an aquifer depends upon its location and structure. A silty matrix of fine-grained material would prevent the alluvium from yielding water. Its location elevated above the water-table would prevent it from furnishing any but perched water. If the alluvium is sufficiently coarse-grained it may be capable of yielding either ground water or perched water, depending upon its position and extent. In general, the alluvium deposits contain the sands, gravels and detrital materials from the Clarno hills, and from the younger basaltic formations. If these are found in sufficient quantities within the ash and tuff matrix of the older formations, a good well can be obtained.

Section 7-5: Summary.

7-5.1 Topography. The reservation has a terrain characterized by plateau lands deeply cut by drainage patterns. The deeply eroded stream beds depress the water-table far below the elevation of the plateaus.

7-5.2 Stratigraphy. The older formations lying at the lower elevations tend to be more dense and impermeable than do the overlying and younger deposits. Since Clarno time (the oldest geologic formation exposed on the reservation) there has been but little orogenic activity to deform the formations on the reservation. Movement of the more permeable overlying materials to the lower elevations, where the water-table is now found, has been generally limited to fluviatile deposits of stream erosion.

7-5.3 Clarno. This is the oldest formation exposed, appearing as fine-grained tuff and clay uplifts in the northeast part of the reservation. The formation is acidic, dense, compact, and generally regarded to be a poor source of ground water. Wells drilled into it invariably have small yields.

7-5.4 John Day. The John Day ash and tuffs overly the Clarno. The tuffs are extremely tight and impermeable, and in places are over a thousand feet in thickness. Except in their top one hundred feet, where they grade into more permeable material, the John Day formation will not yield water to wells in usable amounts.

7-5.5 Columbia River. The Columbia River Basalt lies upon the John Day formation, and in places directly overlies the Clarno. In places the basalt is interbedded with ash from the John Day. At the upper levels of the basalt it is vesicular and fractured. Usually these interconnected gas pockets and joints are above the water-table and are devoid of ground water. At the lower levels, the basalt is so dense and tight that it is not considered to be an aquifer.

7-5.6 The Dalles. The Dalles formation followed the Columbia River Basalt. It is a thick formation, sometimes exceeding one thousand feet. The formation consists of sediments and basaltic flows. The sediments, sometimes fine-grained, are often cemented. These are regarded as only a moderate water-bearing formation. The basaltic materials are highly vesicular and fractured, and are capable of producing strong wells.

7-5.7 The Cascan. The Cascan formation is an andesitic, rhyolitic and basaltic lava flow that today appears as a porous and permeable rock mantle over the western portion of the reservation. The formation lies above the water-table.

7-5.8 Intra-canyon. The Intra-canyon basalts flowed into the present channel of the Metolius and Deschutes Rivers at the southeastern part of the reservation. The formation is localized in the present channel, its main mass lying above the water-table. It has little importance as an aquifer on the reservation.

7-5.9 Aquifers on Reservation. The rock formations that have a structure favorable to yield a minimum of approximately ten gallons per minute to a well are practically restricted to Clarno, Columbia River Basalt, Dalles, Cascan, and recent alluvium. The upland surfaces of the reservation are generally waterless during the summer season.

7-5.10 Surface Permeability. Permeable rock lies exposed, or close to the ground surface, on much of the topography of the reservation. This presents seepage problems in design of unlined hydraulic structures.

CHAPTER VIII

SPRINGS ON THE RESERVATION

Numerous perennial springs outcrop on the central and eastern portion of the reservation to offer sources of ground water for domestic and range use. Many of the springs show decreased flow towards the end of the summer or fall, but few cease to flow entirely. At present, relatively few of the springs have been fully developed. A serious contamination problem exists where inadequately developed springs are used for domestic purposes. There is evidence of damage to unprotected range springs due to trampling, even to the point of complete closure.

Section 8-1: Records and Source of Data.

8-1.1 Existing Data. A previously compiled inventory of descriptions of springs issuing on the reservation is not known to exist. A print of a map (77) upon which is plotted some of the springs is on file at the Agency Land Operations Office. Classification of the springs is shown by symbols on the map, according to their being developed or undeveloped. No information regarding magnitude of discharge or other flow characteristics is given. Locations of the larger springs on the reservation are also shown on various printed maps compiled by the Bureau of Indian Affairs. A general description of stock water conditions for different areas of the reservation appears in a range report of 1939 compiled by the Bureau of Indian Affairs (79, pp. 79-88). No detailed information is given.

8-1.2 Inventory, 1959. During the summer of 1959 an inventory was made of existing springs lying generally east of Range 10 East. No attempt was made to evaluate the springs lying in the timbered foothills to the west. The numerous springs, seepages and spring-fed surface drainage-ways appearing in the westerly portion of the reservation provide an abundance of water for stock or for future domestic development.

8-1.3 An estimate was made in the 1959 spring inventory of discharge. Flow of developed springs discharging through a conduit was measured by catching a measured quantity of water in a known time. Flow from undeveloped springs was estimated by visual observation of effective velocity and cross-section of flow. Approximately 80 percent of the 160 springs and effluent areas investigated are undeveloped, often appearing as diffuse effluent seepage areas. At locations of seepage having well-defined point of discharge, the magnitude of total discharge could be approximated with but questionable accuracy. Numerous moist areas showing no visible flow, but indicating capillary moisture from the proximate water-table, were not recorded.

8-1.4 Springs known to have intermittent or marked seasonal fluctuations were indicated on the inventory. However, most of the springs investigated on the reservation are reported to have generally well-sustained flow.

8-1.5 Inventory Tabulation. A tabulation of springs reported by the inventory appears in Appendix VIII-A. These springs are plotted on U. S. Geological Survey Quadrangles which appear in Appendix VIII-B.

Section 8-2: Classification.

8-2.1 Size. Of the 160 non-thermal springs and seepage areas reported in the inventory of 1959, six were of the fifth order of magnitude. These fifth order springs showed discharges ranging from 10 to 20 gallons per minute. Approximately 60 of the springs reported appear to be of the sixth magnitude having discharges from 1 to 10 gallons per minute. With the exception of the six thermal springs in the vicinity of Hot Springs, and seven non-thermal springs which were reported as being dry, the remainder have discharges which are indicated as being unknown. The springs listed as having unknown discharge are probably of sixth, seventh, or eighth magnitude.

8-2.2 There are numerous places at which no visible discharge occurs but where the ground appears constantly moist. In these places where the water-table, or perched water-table lies close to the ground surface, capillary water feeds a lush and green vegetation. It is likely that many of these unreported areas showing evidence of proximate underlying water could be developed into springs of seventh or eighth magnitude. Where these moist areas occur remote from other visible strong springs or perennial streams, their development could greatly improve stock water facilities.

8-2.3 Although many of the springs on the reservation reportedly discharge at a reduced rate during the latter summer months, they are in general perennial springs of sufficiently sustained flow to be satisfactory for either domestic or stock use. Fluctuations in discharge appear to be generally limited to seasonal cycles, and appear pronounced only at the end of prolonged dry periods. Springs reported as having flowed perennially in past years, but which now are dry, appear to have been damaged by access to stock. An example of the permanent sealing of a perennial spring by rock occurs at the southeast quarter of Section 7, Township 7 South, Range 11 East. The spring, formerly known as Mud Spring, is now dry, although indications of capillarity appear further down the watershed.

8-2.4 The springs which appear on the reservation are of a size which limits their use generally to stock water or domestic consumption. Although no non-thermal spring discharges in sufficient quantities to be a significant source of field crop irrigation, many are of sufficient size for watering of small garden plots.

8-2.5 Formation. The springs on the reservation appear to issue generally from formations described by type II, III, V and VI of Tolman's classification of paragraph 3-1.3. These are (II) springs issuing from thick permeable formation, (III) springs issuing from interstratified permeable and impermeable formation, (V) springs issuing from lava, and (VI) springs issuing from fractures.

8-2.6 The Cascan formation on the reservation has the depth and permeability to generally yield springs of type II or V. Except in the westerly portion of the reservation, the Cascan usually lies above the water-table, and is devoid of water.

8-2.7 Springs of the type III issue from the interstratified permeable beds in the John Day and Dalles formation. These formations, both containing fluviatile beds of permeable materials, often yield small contact springs at the upper contact of the impermeable member. The issuing water, which is apparently often perched water, usually remains at the ground surface throughout the outcrop of the impermeable formation. At the upper contact of a more permeable underlying member, the water percolates downward and no longer remains visible at the ground surface. At a lower elevation in the watershed another underlying impermeable barrier may again outcrop and again bring the same water to the surface. This process may be repeated several times along a sloping terrain. The reappearance of spring water that has been previously exposed to surface contamination is of grave concern when used for domestic purposes.

8-2.8 Springs of type III are common on the reservation. The springs that flow into the Seekseequa, Tenino, and Shitike Creek drainage emerge from the more permeable interstratified members of the Dalles formation. Although these springs are found in a portion of the reservation having but 10 to 11 inches of precipitation per year, the springs are reasonably sustained.

8-2.9 Springs of type V that issue from lava occur in the Columbia River Basalt at its contact with the underlying John Day formation, and possibly at the extreme westerly part of the reservation from the Cascan formation. Examples of the springs from the Columbia basalt are those that flow from the base of North Block and South Block, two plateaus of Columbia River Basalt that lie northeast of the Agency and west of South Junction. Springs flow out onto the John Day formation at its upper contact with the basalt.

8-2.10 Springs from lava occur in the Intracanyon basalts and also in the basaltic members of the Dalles formation. These springs do not constitute an important source of water on the reservation, for they are found only in the immediate vicinity of the Metolius and Deschutes Rivers.

8-2.11 Springs of the type VI, those which issue from fractures, are found in the fractured tuffs of the Mutton Mountains and other surrounding Clarno hills. The Clarno formation does not appear to have a clearly defined water-table (54, p. 192), and contains springs at widely scattered stratigraphic locations. These springs vary widely in magnitude of discharge.

8-2.12 Continuity of Flow. Although the non-thermal springs on the reservation issue a reduced discharge after the prolonged dry summer period, there are but few springs that can be classified as intermittent.

In general the springs are perennial. The sustained flow from these springs, located in a region of low rainfall, appears due to a highly permeable soil mantle which permits little surface run-off, and due to relatively impermeable subsurface formations which retard underground water velocities. Formations such as the John Day ash and the finer grained Dalles sediments have high specific retention. The fact that the limited underground storage capacity furnishes water to the numerous perennial springs is due to the ability of the relatively impermeable and tight members to hold back the downward flow of percolating water, metering the water to points of seepage sufficiently slow rates to provide year-round flow.

8-2.13 It is probable that many of the springs found at higher elevations discharge perched water. Usually, these springs are the weaker in discharge, and are the first to suffer at the end of a prolonged dry period. Springs which issue perched water from localized barriers draw from underground reservoirs of but limited capacity. At the close of summer or fall, the reservoir is depleted. The spring remains dry until the fall and winter precipitation recharges the perched reservoir.

8-2.14 The position of the water-table on the reservation has never been clearly established. Incomplete well logs from the few existing wells do not constitute sufficient information to locate the position of the water-table, or to determine its seasonal fluctuations. Although the water-table is necessarily depressed in the canyons to the level of the perennial surface streams, it is probable that the gradient of the water-table rises quite steeply in the tight and relatively impermeable formations through which the canyons have eroded.

8-2.15 Artesian Springs. There is no evidence of artesian springs discharging non-thermal waters. All spring discharge in the eastern portion of the reservation appears to be of the gravity type, whether discharging waters from the water-table or from a perched source. Many of the springs issue diffuse seepage having no clearly defined orifice.

8-2.16 Thermal Springs. Thermal springs occur along the Warm Springs River in Sections 19 and 20, Township 8 South, Range 13 East. These springs issue at points about 1500 feet above sea level, and apparently have their origin from far below the surface of the earth. With the exception of Kah-Ne-Ta Spring which is owned fee simple by a non-resident, all of the thermal springs are on Indian land. Areas of localized warmer water in the Warm Springs River suggest additional but unlocated thermal springs that issue directly into the river.

8-2.17 Although the water has a faint sulphurous odor, it is clear and generally tasteless. The hottest spring discharges water at 182°F. During the summer of 1940 Joseph E. Upson (85) investigated the Kah-Ne-Ta and adjacent springs. The complete text of Upson's report appears in Appendix IX-G. A tabulation of the features of Kah-Ne-Ta Spring and adjacent hot springs appears in Appendix VIII-C.

Section 8-3: Occurrence of Springs.

8-3.1 Regional Distribution. With the exception of the timbered easterly slopes of the Cascade Range which form the westerly portion of the reservation, the Mutton Mountains, surrounding Clarno hills and Columbia River basaltic plateaus in the northeast issue the greatest non-thermal spring discharge, both in total magnitude of discharge and in area density. In this area approximately 70 percent of the range land lies within a radius of one mile of a spring or seepage area, existing well or accessible perennial surface water. Within this area, lands on the north and east slopes of the Mutton Mountains are the most deficient of water. Here, springs are generally undeveloped, and many go dry near the end of summer. Diffuse seepage which is now practically ineffective as sources of stock water could be developed to improve range conditions.

8-3.2 The Metolius Bench, Tenino Bench, and Dry Hollow areas are generally deficient in spring discharge. Approximately 50 percent of this range land lies within a radius of one mile of available water, approximately 75 percent lies within one and one-half miles of available water. The Metolius and Deschutes Rivers although bordering the land to the south and east lie in canyons so steep and deeply cut as to be practically inaccessible. These areas are characterized by thick interstratified Dalles deposits. Stock ranging on the comparatively even terrain of these plateaus has access to spring water only at the edges of the plateaus where eroded by deeply cut drainages of Metolius and Deschutes Rivers, and Seekseequa and Tenino Creeks.

8-3.3 Schoolie Flat, Miller Flat, Sidwalder Flat and the Island are practically devoid of spring discharge. Springs issuing from the westerly toe of the Mutton Mountains provide some ground water for the easterly portion of Schoolie Flat. Five springs exist on Miller Flat. The existing irrigation unit on Sidwalder Flat provides surface water for range lands in the absence of spring discharge. The unbroken plateau portion of the Island contains no springs. Springs issuing at the lower canyon walls into Mill Creek, Beaver Creek and Warm Springs River are too inaccessible to be of much importance.

8-3.4 Topographic Distribution. The existence of accessible springs is most favorable on the reservation where the topography is characterized by uneven terrain not excessively steeply eroded. The Mutton Mountains and the Clarno hills in the vicinity of Simnasho are topographically suited for the occurrence of springs. Here small springs issue from the lower reaches of the Clarno formation or its lower contact with the John Day tuffs. These springs occur at locations accessible to stock, or proximate to existing home sites.

8-3.5 The north edge of the Metolius Bench, being cut by Seekseequa Creek in a deep drainage that contains long finger gullies projecting deeply into the bench, proved accessible springs that are favorably removed from the perennial surface waters of Seekseequa Creek. Springs that issue from the lower elevation of the steep face of the Metolius Canyon along the south edge of the bench have little importance as a source of either domestic or stock water.

8-3.6 Topographically, the level plateau lands that are adjacent to sheer and deeply cut canyons are unlikely to receive spring water. Such is the position of such plateau lands as the Island, the western portion of Schoolie Flat, Tenino Bench, the southern portion of Metolius Bench and most of Miller Flat and Sidwalder Flat.

8-3.7 Geologic Structure and Texture. Because the reservation lies in an area receiving small amounts of annual precipitation, the existence of numerous perennial springs is due to the relatively impermeable nature of the lower geologic formations. With the exception of exposed John Day formation, the soil mantle is highly permeable. This effectively minimizes surface run-off. Here the rain and snow melt readily enters the porous and permeable mantle, to percolate downward to become perched on localized impermeable barriers or to continue downward to the water-table.

8-3.8 The subterranean formations generally decrease in porosity and permeability at the lower depths. Because of the dense and tight nature of rock in the deep strata, and because of the meager annual precipitation received on the reservation, the underground water storage capacity is severely limited. That the deeply eroded canyons do not immediately deplete the available stored ground water is probably due to inability of the waters to travel underground in the permeable tuffs and rocks with even a moderate velocity. Seepage is in most cases on the reservation metered out at sufficiently slow rates to sustain the flow until periods of seasonal recharge.

8-3.9 Permeability of the exposed topography along a drainage-way is variable. Water issuing from a spring may flow along the surface of a drainage-way where an impermeable formation is exposed. At a point where the permeability increases the water may again re-enter the ground. It remains underground until a lower impermeable stratum again forces the water to the ground surface. In such conditions, the same water may reappear several times as spring discharge. There appear to be several locations on the reservation where this type spring discharge occurs. The dangers of pollution from upland surface contaminants is discussed in paragraph 8-4.4.

Section 8-4: Water Quality.

8-4.1 Hardness. Water issuing from the non-thermal springs on the reservation is usually soft. Although no chemical analysis is known to have been made on the spring waters, no excessive carbonate or non-carbonate hardness is apparent. It would be expected that the spring waters would be slightly harder than the surface waters of the Deschutes which have approximately 80 parts per millions of dissolved solids, mostly carbonates. See paragraph 6-3.6. Throughout the reservation the spring water is reported to respond readily to soap, indicating a soft water.

8-4.2 Turbidity. Except where subject to surface contamination, the waters that issue from the springs appear to be clear, and free from turbidity. At all springs where turbidity was observed, the foreign material appeared to be of organic origin from surface contamination.

8-4.3 Pollution. Pollution of spring water used for domestic purposes is a serious threat to health of the residents of the reservation. A survey of 1958 conducted by the Division of Indian Health of the Department of Health, Education and Welfare (69, p. 21) reports 7 of 13 springs used for domestic use are not approved because of pollution.

8-4.4 Pollution of spring water on the reservation has occurred because of inadequate protection of the spring orifice and inadequate protection of the spring water collecting basin. Although some contamination undoubtedly occurs at water courses above the spring orifice where the spring water may be momentarily exposed, it appears that most of the pollution is a result of animal and human contamination at the spring itself. See paragraph 8-3.9.

8-4.5 That many of the springs on the reservation have been allowed to become polluted is unfortunate. Once the soil at the spring orifice has been permitted to become heavily contaminated with pathogenic organisms it is often difficult to again receive untreated water safe for human consumption. Although the coliform bacteria which give rise to typhoid fever, and bacillary dysentery will not sustain themselves for long in clean water, they are extremely persistent in the environment of a heavily contaminated soil. A matter of concern is evaluating the relative danger of the spread of enteric infections is the large number of pathogenic organisms included in the excreta of carriers. A carrier of typhoid fever may excrete up to 200 billion S. typhosa per day. Statistical evidence indicates that one to two percent of the persons who ingest a single viable egg of S. typhosa contracts the disease.

8-4.6 Suggested measures to be taken for preventing pollution of spring water are discussed in paragraph 8-7.1. Water treatment procedures are discussed in paragraph 10-6.1.

Section 8-5: Duty of Spring Water.

8-5.1 Domestic. The springs on the reservation have in general a magnitude of discharge, continuity of flow, quality and location that is favorable for domestic use. Nearly all the perennial springs reported in the inventory of 1959, Appendix VII-A, have discharges in excess of average household requirements. Although most of the springs show a diminished flow late in the summer or fall, the minmum daily discharge of the perennial springs is adequate when supplemented by a small storage tank. The topography and geology of the watershed and subterranean conduits are favorable for unpolluted water supply. With reasonable precaution for pollution prevention, the springs are ideal as a source of readily available safe untreated water. Many of the springs are located at positions favorable for gravity systems to dwelling sites.

8-5.2 Stock. Springs are a most important source of range stock water on the reservation. There are only a few places on the reservation where water having its source from perennial springs or other perennial surface drainage is not accessible within a radius of a mile and one-half. Although most of the springs are at present undeveloped, more than 50 percent are of sixth magnitude. There are areas remote from existing springs or other perennial surface drainage that appear moist throughout the summer which could probably be developed to discharges sufficiently strong for stock water. See paragraph 8-2.2.

8-5.3 Irrigation. There appear to be no springs on the reservation of sufficient discharge or of favorable location to enable direct field crop irrigation. Springs of a magnitude enabling small garden plot irrigation are found in various locations. However, the discharge from most of the springs is so small, that irrigation of garden plots could be best done by drawing water periodically from small water-tight reservoirs that are continually recharged from the spring delivery.

Section 8-6: Present Development.

8-6.1 Domestic. Approximately 50 percent of the springs used for domestic purposes have been found to yield polluted water. The report by the Division of Indian Health referred to in paragraph 8-3.4 does not describe the nature of development, if any, of the unsafe springs. It is concluded from the spring inventory of 1959 that the privately developed springs do not provide sufficient protection against pollution.

8-6.2 No spring developments using wooden materials for construction of collecting basins, or for fabrication of covers or lids to masonry basins are in a satisfactory condition of maintenance to prevent pollution. Although wooden material may effectively provide adequate protection when first installed, it lacks permanence and is soon unsafe. Wooden construction for spring development structures may be considered to be unsatisfactory.

8-6.3 The springs developed for domestic use are generally not sufficiently fenced off or otherwise protected to prevent access to either stock or humans. There appears to be little or no provision for protection against entry of surface waters into the spring. Invariably, where the point of delivery is at the spring orifice, the ground adjacent to the spring shows evidence of contamination. Without exception, the point of delivery of the water should be remote from the spring orifice.

8-6.4 The lack of protection against pollution is the most important single factor pertaining to domestic developed springs on the reservation. The springs developed for domestic purposes appear to have been the stronger springs when in their original undeveloped condition. The stronger springs on the reservation, having a well defined orifice, do not present a particularly difficult problem in development of discharge to meet household or farmstead requirements. In such cases, the important factor in spring development is not to attempt to increase discharge at the orifice, but to protect the waters from pollution.

8-6.5 Stock. The springs now used solely for range stock water are usually undeveloped. Stock springs that have been developed are generally those that have been improved by the Civilian Conservation Corps and by the Agency Land Operations Office. The older developments are now generally in a poor state of repair. Agency developed range springs have been recently developed and are usually in good condition.

8-6.6 While pollution of springs by access to stock is always a possibility, particularly if other springs at lower elevations of the same watershed are used for domestic purposes, the principal danger lies in the physical damage to the spring orifice. Many of the undeveloped springs which are free to stock entry, are so severely trampled that the orifice appears in danger of being sealed. Where this occurs the water is not able to issue from the impermeable muck, or is severely restricted. Water failing to appear through the ground surface at the damaged spring area may reappear further down the watershed, but at such a distance that a considerable area or range is lost to effective grazing. Often the water may not appear again until it is nearly at the bank of a perennial stream. A spring at such a proximate location to a stream has little if any value for range management.

8-6.7 The weaker diffuse springs which are often remote from other sources of water are the most easily destroyed. Here the numerous but minute orifices are easily cut off, and the spring because it is the sole source of water is greatly used by stock. It is a paradox that such a spring because of its location is so vital for stock range, yet is the spring most likely to be completely lost if unprotected.

8-6.8 An example of a stock damaged spring is the spring known as Mud Springs on the Metolius Bench, and previously described in paragraph 8-2.3. The spring has been reported by residents to be formerly a strong spring. The spring is now dry. As range water is extremely scarce in this area, the loss of this spring is unfortunate. Remaining evidence of capillarity near the spring suggests that the water could again be made available, but with considerable development cost.

8-6.9 Cost of Development. The Agency Land Operations Office (75) reports normal labor charges for spring development to be about 20 percent of material costs. The average total cost for development of four reported springs is about $600.00 per spring. The greatest single item, being the cost of iron pipe, suggests the advisability of investigating the use of plastic pipe buried by a sub-soil mole. Where plastic pipe is laid on gradients allowing minimum hydro-static pressures in the pipe, the pipe may be expected to be serviceable and free from the failures sometimes associated with plastic pipe. Plastic pipe is resistant to rust, rot and corrosion. It has an excellent carrying capacity which does not diminish with age. The cost ratio of steel to plastic pipe for one inch diameter size is approximately two to one. Savings in fittings such as couplings and elbows are considerable when using plastic. The possible savings in both labor and material for spring development warrant investigation.

8-6.10 The cost of drainage conduit or infiltration gallery has not constituted a major cost of the existing spring developments. Springs now developed on the reservation are in general those having a well-defined point of discharge. These springs in general are the easiest to develop from a standpoint of collecting the water, requiring only rudimentary collecting conduits or galleries.

Section 8-7: Future Development.

8-7.1 Domestic. Primary emphasis for domestic development should be placed on elimination of pollution. The essential features to be remembered in the development of a spring for domestic purposes are (1) to prevent surface water from entering the spring, and (2) to prevent contaminants from either humans or animals from entering the spring. Protection of spring water requires the same considerations of pollution as do wells. See paragraphs 3-4.6 and 4-9.1. Where the weaker springs or diffuse seepage areas are to be developed, additional attention need be directed to the drainage or infiltration gallery.

8-7.2 Springs which are developed on the reservation, particularly springs intended as sources for domestic water, should be developed only under the supervision of the Department of Health, or other qualified agencies. There are many bulletins, brochures and reference sources providing excellent specification for spring improvement. References 2, 3, 5, 11, 14, 26, 44, 45, 60, 64 tabulated in the bibliography of this report are a few of the many sources of such information.

8-7.3 Stock. Primary emphasis for spring improvement for stock range should be placed on the protection against orifice obliteration due to stock access. The danger of sealing off the weaker springs at the higher altitudes is of particular concern for these springs, which are usually the most remote from perennial surface waters or other springs, are the most easily damaged because of their naturally small discharge.

8-7.4 Although the immediate danger of sealing the stronger springs found at lower elevations is not as great as that to the weaker seepages, nevertheless, the danger does still exist. The sealing off of a spring by stock may be a slow process. It may take years to seal off the stronger springs having a well defined orifice, for the stronger flows keep the fine grained materials flushed away. But if stock has continual access to these stronger springs, the orifice may deteriorate to become merely a seepage area. When this happens, complete obliteration of the spring soon follows.

8-7.5 Where the possibility exists for spring withdrawals at the lower elevations for domestic use of water that has previously issued from springs at higher elevations, precautions should be taken to prevent contamination. Watering points should not only be remote from the spring orifice, but should not be located on the drainage-way lying between the spring and the domestic spring lying below.

8-7.6 Spring Development vs. Drilled Wells. Because springs are fairly well distributed over the reservation, two alternatives exist at some locations for obtaining ground water for domestic and other farmstead activities: (1) spring water delivered by pipe distribution system, or (2) a well located at or close to the homesite. Each has advantages and disadvantages which are:

I. Where the spring lies at considerable distance from the homesite, the cost of the pipe and labor for installation may far exceed costs of well drilling. Assuming labor costs as being 20 percent of material costs of laying one and one-half inch galvanized pipe, a six inch well can be drilled to a depth of 100 feet for approximately the same cost that 900 feet of the iron pipe can be installed. If flexible plastic pipe rated at 75 pounds per square inch were installed using powered placement, approximately three-eighths of a mile of distribution line having design capacity equal to the 900 feet of 1 1/2 inch iron pipe could be installed.

II. Where spring development is utilized, it is known in advance what available discharge to anticipate, whereas the discharge from a well is not known until after considerable funds are expended. Although deep wells on the reservation have never developed to be strong producers, there is nevertheless very little history of complete well failures or dry holes. Even on the plateaus, discharges meeting household and farmstead requirements are received from wells having depths less than 600 feet.

III. Although both springs and wells can furnish water to distribution systems without the use of electricity, wells driven by windmills may be considered undesirable because of the unreliability of the source of power. Where an adequate reservoir system is provided, which is essential to development by either a spring or a well, it is questionable if a windmill is unsatisfactory.

IV. Where springs exist within economic distances from a farmstead, their development is preferred to that of drilling a well. Well drillers in the Deschutes Basin (1) are of the opinion that often water brought in by drilled wells is from perched sources that would eventually find its way to springs at lower elevations. If this is so, it is also possible that water brought in by drilled wells may be in part water that previously issued from springs at higher elevations and then re-entered the ground at a permeable outcrop below the spring, thereby percolating downward to recharge the perched aquifer of the well. Under such conditions, the perched well would probably have little, if any, improved performance over the proximate springs.

V. In general, farmsteads are so far removed from each other that extensive distribution systems for central spring development would involve such long lengths to be impractical.

8-7.7 Spring Development on Schoolie Flat. Domestic water at Schoolie Flat is of particular concern both from the standpoint of the number of people deprived of adequate water facilities, and of the physical difficulty in obtaining ground water in this particular area. The possibility of obtaining ground water by drilled wells in this area is discussed in detail in section 9-8. The alternative source of ground water is from the springs that issue along the west toe of the Mutton Mountains.

8-7.8 A preliminary plan for the development of three springs and the required distribution system to serve a portion of Schoolie Flat has been proposed by the Agency Land Operations Office (75). The three springs considered are the Spino spring on allotment 149, the Tewee spring on allotment 215, and the Dick spring on allotment 666. The three springs now have a total discharge of approximately 18 gallons per minute. The Dick spring which is now a series of undeveloped springs and seepage having a discharge of about 10 gallons per minute appears on the same watershed and above the Spino spring. The Spino spring discharges about six gallons per minute in a series of undeveloped seepage areas. Intermittent capillarity evident on the ground surface between the Spino spring and the Dick spring indicates that if the discharge of the Dick spring was drawn off that the Spino spring would practically cease to flow. In this event, there would remain about 12 gallons per minute entering the distribution system to serve the existing 20 homes on Schoolie Flat.

8-7.9 The total estimated cost of this development which includes spring developments, reservoir and necessary distribution lines to 20 homes is reported as approximately $41,000. The estimate prepared by the Agency Land Operations Office is preliminary. However, the high cost of a distribution system that has a source of water having such questionable capacity is a strong point in disfavor for this plan. For this reason, such a plan is not recommended. Ground water development on Schoolie Flat by drilled wells appears to offer a more practical solution for areas not adjacent to spring flow. See paragraph 8-7.6 I.

Section 8-8: Summary.

8-8.1 Classification. All the springs are non-thermal except a group of springs at Hot Springs on the Warm Springs River. It is not known if waters issuing from these thermal springs are of magmatic or meteoric origin. The non-thermal springs on the central and eastern portion of the reservation are generally of sixth or seventh magnitude. Although discharge of these springs is reduced towards the end of the prolonged dry summer season, most are perennial. Both so-called "contact" springs and areas of diffuse effluent seepage are found. In places no visible flow occurs, but the presence of capillary water indicates a readily available source of ground water of limited developed capacity. With the exception of possible artesian flow in lava springs at the western edge of the reservation and the thermal springs at Hot Springs, the springs on the reservation are of the gravity type and not subject to hydro-static pressures.

8-8.2 Occurrence. The occurrence of springs on the reservation is most favorable where the terrain is characterized by uneven topography having widespread and well defined drainage patterns. With the exception of the area outcropped by the John Day tuffs, most of the soil mantle of the reservation is sufficiently permeable to allow but little run-off. The occurrence of the numerous springs in a region of scant precipitation is due to slow percolation through generally tight strata at the deeper depths. The Clarno hills and Columbia River Basalt plateaus on the northeast section of the reservation are sources from which many springs issue. The benches towards the south of the reservation lie in a region of less recharge from precipitation and have extensive areas of generally unbroken terrain. In such environment, springs are found only sparingly.

8-8.3 Duty and Quality. Discharge of springs on the reservation is of a size limiting them to domestic and stock use. With exception of being sources of supplemental water to small garden plots, they have no value for direct irrigation. The water is good tasting, is not turbid, and is sufficiently soft to be satisfactory for household use. Although the geologic structure is favorable for sources of uncontaminated spring water, approximately 50 percent of the springs used for household use yield polluted water.

8-8.4 Present Development. In general the springs that are used for domestic purposes have not been protected sufficiently to assure water free from pollution. Where springs have been developed, the locating of the orifice or the installation of infiltration gallery has not been the main problem, as these springs appear to have had well established orifices. It is apparent that inadequate precautions have been generally exercised in providing entry of contaminants to either developed or undeveloped springs used for household use. In all cases, developments using wooden construction are unsatisfactory. Invariably, where point of water delivery is at the orifice, or where stock has access to the area adjacent to the orifice, the ground surrounding the spring appears heavily contaminated.

8-8.5 The recent range developments appear to be well designed, and are in a good repair. Older developments are in advanced stages of deterioration. Where stock has access to the spring orifice, the spring is in danger of being obliterated. This is likely where the spring has a naturally weak discharge that emits from an orifice having no well-defined location. Many of the springs, now dry or intermittent, which were reportedly perennial, appear to have been cut off by the trampling of stock. Once a spring has been sealed and the ground water forced to re-establish a subsurface conduit, it is often difficult to again bring the water to the surface. When a spring that serves as the sole source of water for a large area is lost, even though it is of small capacity, the loss is great.

8-8.6 Future Development. The most urgent requirement of springs developed for domestic needs is the immediate correction of conditions contributing to pollution. Perennial springs on the reservation are sufficiently numerous and distributed to serve as a valuable source of ground water for both farmsteads and range water. Where springs issue sufficiently close to existing farmstead areas, a distribution system and reservoir served by spring development offers a solution to domestic water. The major cost of such a plan is often the cost of distribution pipe. Where an extensive area of low population density is to be served by springs into a common distribution system, the cost of pipe may be so great that other sources for water appear a better choice.

8-8.7 The most urgent requirement of springs now used for range water is the prevention of stock access to the spring orifice. Springs that are at the higher elevation, that are the farther removed from other sources of perennial streams have most urgent need for immediate development. It is these springs that are often most readily damaged by stock access. Because these springs are often the weaker springs and have poorly defined orifices, the use of properly designed infiltration galleries to receive adequate drainage is of importance.

Section 8-9: Recommendations.

8-9.1 Pollution. It is suggested that all springs developed for domestic use be improved and maintained in accordance with recognized sanitation practices. Because the pollution of water from springs is a direct menace to the health of the residents, the immediate correction of the existing sanitation deficiencies of spring development is recommended. Springs developed for range water should be subject to the same sanitation requirements as those springs primarily used for domestic use. Where it is apparent that springs issue water that has previously flowed on the ground surface at higher elevation, precautions should be taken to prevent contamination at the higher topography.

8-9.2 Protection. Many of the weaker areas of diffuse seepage on the reservation are now in danger of partial or complete sealing due to unlimited access of stock. Where these springs, due to their advantageous location, have value for range management, their immediate development is recommended. It is a poor practice to let stock have access to any spring orifice, regardless of spring size, type of development or degree of sustained flow. A program of range spring development should be vigorously pursued.

8-9.3 Integrated Development and Distribution. Where spring development is contemplated involving an extensive buried pipe distribution system, such as at Schoolie Flat, the high cost of the pipe to serve a widely dispersed area may impose an uneconomical limitation. Although deep wells on the reservation are not likely to produce sustained yields greater than five gallons per minute, ground water from wells may be the most economical and feasible alternative. A proposed plan to serve 20 homes on Schoolie Flat from springs having an anticipated total discharge of 12 gallons per minute that lie on the east edge of the flat does not appear to be a favorable plan. Although farmsteads on Schoolie Flat proximate to the springs could be most economically served by the springs, the area lying farther to the west could be probably better served by a few deep wells having independent distribution systems.

8-9.4 Discharge Data. Accurate discharge measurements are needed for all springs on the reservation. The need for better data is required for the proper planning of spring development for both range or domestic uses. It is recommended that a program of discharge measurements be made at approximately monthly intervals to establish the minimum seasonal flows of both developed and undeveloped springs.

CHAPTER IX

WELLS ON THE RESERVATION

In general, deep wells on the reservation are capable of producing only the small amounts of water sufficient for domestic or stock use. Any irrigation from these wells must be limited to supplying water for garden plots. On the plateaus, wells drilled to depths of five or six hundred feet may yield a maximum of five to ten gallons per minute. Often smaller yields are obtained. Small amounts of annual precipitation, deep formations having little permeability and porosity, and a topography that is deeply eroded are factors contributing to the usual poor performance of deep wells on the reservation.

Shallow wells, drilled into the coarser alluvial deposits at the valley floors and proximate to perennial streams are better producers. Such wells often show discharges in excess of fifteen gallons per minute with very little drawdown.

Section 9-1: Records and Source of Data.

9-1.1 Ground Water Investigation. There has been greater ground water investigation at the Schoolie Flat area than elsewhere on the reservation. An existing well on the Schoolie Flat is the only well on the reservation known to have had a reasonably complete pumping test. A report of December 1955 by Brown (6) describes a performance test of the Frank Suppah well. A copy of this report appears in Appendix IX-C. After the Suppah test was completed, a brief report was submitted by Flohrschutz (13), further discussing the results of the pumping test, and considering the use of springs for supplying water to this area. A copy of the Flohrschutz report appears in Appendix IX-D. During the early part of 1956 Newcomb and Hogenson (40) of the U. S. Geological Survey, Portland, conducted an investigation of the ground water problem at Schoolie Flat and the surrounding areas. The purpose of the study was directed specifically toward a solution for domestic water at Schoolie Flat. Their report which appears in Appendix IX-E suggests several locations where proposed well construction appears to be most favorable.

9-1.2 A preliminary report by Henderson (21) describing a possible domestic water supply to Schoolie Flat from proposed wells at the confluence of Coyote Creek appears in Appendix IX-F. The report, submitted August 1, 1959, describes the wells, and distribution system required to serve Simnasho and the Schoolie Flat area. The selection of proposed wells at the mouth of Coyote Creek was based upon conclusions formed earlier by Newcomb and Hogenson (40).

9-1.3 In 1960 the Agency Land Operation Office (75) prepared a preliminary estimate for the development of springs to serve Schoolie Flat. A discussion of this study appears in paragraph 8-7.8. The estimate and plan of development does not include a discussion of ground water capacity of the springs proposed for development. Discharges indicated in paragraph 8-7.8 are those observed by the author of this report during the summer of 1960.

9-1.4 During the summer of 1940 Joseph E. Upson (85) investigated the Kah-Ne-Tah Spring and adjacent thermal springs. A text of his report appears in Appendix IX-G. The report confines its investigation primarily to the ground waters issuing from the thermal springs.

9-1.5 Test holes on the reservation have been drilled near proposed or existing dams on the Deschutes and Metolius Rivers. Abrams (1) describes test holes that penetrate into impermeable John Day beds near the reregulating dam below the Pelton dam. A test hole drilled by Portland General Electric Co. (49) near the proposed Round Butte dam is described by a log appearing in Appendix IX-H.

9-1.6 Considerable investigation for ground water has been conducted for areas adjacent to the reservation. One of the first of these was conducted by Israell C. Russel (52) during the summer of 1903. The field work was authorized under the joint auspices of the western section of hydrology and division of geology and paleontology of the U. S. Geological Survey. The report, appeared in the U. S. Geological Survey Bulletin #252. Russell's main purpose for conducting his survey was reportedly to indicate where artesian water could be secured in the Deschutes basin off the reservation.

9-1.7 During the summer of 1925, Harold T. Stearns (53) investigated dam sites on the Crooked River from its mouth to Trail Crossing. Part of this time was devoted to reconnaissance of the Deschutes River basin. The ground water situation east of the reservation is discussed. A report appeared in 1931 in the U. S. Geological Survey Water-Supply Paper no. 637-D.

9-1.8 Well Logs and Performance Records. The U. S. Geological Survey, Portland Branch has compiled available information from driller's logs and well performance tests on Well Schedule Form 9-185 (83). Available information from drillers' logs is in nearly all cases far less than that permitted at the time of drilling. The drilled wells on the reservation have in all cases been constructed by cable-tool equipment, a method of construction that inherently is adapted to accurate sub-surface sampling and static water level measurement. It is unfortunate that the opportunity to obtain the valuable geologic information has not been exploited at the time of drilling. Performance tests have generally been limited to bailing tests of short duration, conducted by the driller. With the exception of the performance test of the Suppah well, described in paragraph 9-1.1, and Appendix IX-C, no sustained pumping test has been made after removal of drilling equipment.

Section 9-2: History of Well Construction.

9-2.1 Shallow Wells. The term "shallow well" has been applied to wells on the reservation that range in depth from the cribbed holes five to ten feet deep which may be more accurately termed as spring or surface water developments, to the drilled or dug wells having depths thirty to fifty feet having steel or masonry casing. Locations of the shallow wells are near perennial streams or near diffuse effluent seepage. The problem of discharge from the shallow wells has not appeared to be a problem. Where these wells have been constructed, the water-table lies sufficiently close to the surface in a permeable formation to adequately supply water for household needs.

9-2.2 There appears to have been little attempt to safeguard the shallow dug wells against pollution. The dug wells usually lack a tight curbing at the ground surface or surface drainage necessary to prevent entry of surface contaminants. Drilled shallow wells have been of rather recent construction and are sufficiently sealed to prevent pollution.

9-2.3 The shallower drilled wells located adjacent to the perennial water-courses or perennial seepage areas of the reservation have yielded water in rates sufficient for domestic or farmstead use. The Freeland well, drilled to a depth of thirty-nine feet near the Warm Springs River at Hot Springs, discharges over thirty gallons per minute with only a one foot drawdown. The Heath well, near the confluence of the Warm Springs River with the Deschutes River, yields twelve gallons per minute with a three foot drawdown in a thirty-four foot well.

9-2.4 Shallow wells have been constructed near points of diffuse effluent seepage or where capillarity indicates the presence of ground water at shallow depths. These wells are not really wells at all, but are sources of ground water from developed springs. As a rule, these wells are dug wells, and often lack provisions for excluding surface contaminants from the water. Such wells usually have magnitude of yield similar to the perennial springs in the vicinity. These wells have been constructed for domestic use, and have sufficient capacity for this purpose.

9-2.5 Shallow wells have been constructed that are served entirely from surface water. These type of shallow wells are found primarily on Sidwalder Flat where surface waters from the Mill Creek Irrigation Unit flow nearly perennially in the canals and laterals. The shallow holes scooped out of the ground serve as collecting basins for the surface waters. Where these untreated waters are used for domestic purposes a serious health hazard exists.

9-2.6 Drilled Deep Wells by Agency Contract, 1935. As a result of a contract awarded to R. J. Strasser of Portland, Oregon, several deep wells were completed on the reservation during 1935. The drilling equipment used on all these wells was of the cable tool or percussion type. Apparently well development procedures of types described in paragraph 4-4.17 were not used. The following wells were completed:

Subdivision Location 1/	Area	Local Name	Depth in Ft.
7/11 - 36M1	Island	Island well	500
7/12 - 7F1	Simnasho	Simnasho well	565

8/11 - 6L1	Sidwalder	Alfred Smith well	407
8/11 - 35P1	Miller	Hoptowit well	320
9/12 - 23A1	Dry Creek	Johnson #3 well (dry)	558 2/
10/12 - 15E1	Dry Hollow	W. Smith well	288
10/12 - 31K1	Metolius	A. Smith well	380 3/
10/12 - 34N1	Metolius	Wewa well	400 4/

1/ For description of subdivision notation see Appendix VIII-A.

2/ Reported elsewhere to have been a dry hole drilled to a depth of 804 feet.

3/ Reported elsewhere to have been drilled by Mr. B. Abrams, at an unknown date. A well described as Johnson #2 located "west of Wewa Well" drilled to 355 feet may be the A. Smith Well.

4/ Well originally drilled by Mr. R. J. Strasser was redrilled in 1948 by Mr. B. Abrams, to depth of 616 feet. Well is now inoperative.

9-2.7 Of the eight percussion drilled wells described in paragraph 9-2.6, only one failed to yield water. Existing well logs are not clear in the description of this dry hole, called the Johnson #3. It was apparently drilled to 558 feet or 804 feet without producing appreciable amounts of water. Sustained yield is known for only the Suppah well, reported to be approximately two gallons per minute.

9-2.8 These wells were designed primarily as sources for stock water. Piston pumps with 1 13/16" cylinders were installed which were powered by fourteen foot windmills. Stock water reservoirs and watering tanks were installed at each well. The windmill installed at Simnasho was later destroyed by a fire. Three of the wells are now inoperative, the Island, the Wewa, and the Alfred Smith well. The Wewa and Island wells are not functioning because of repeated cave-ins or silting.

9-2.9 Recently Drilled Wells. Since the drilling of the original contracted wells in 1935, several drilled wells have been constructed on the reservation. These wells have usually been drilled to shallower depths than were the wells constructed in 1935. A tabulation of these drilled wells are:

Subdivision Location	Area	Local Name	Depth (Ft.)	Date Completed
7/12 - 34L1	Schoolie	Suppah	300	1950
8/12 - 4R1	Schoolie	Tootick	139	1958
8/13 - 9K1	Mutton Mtns.	Charley	125	1959
8/13 - 20G1	Hot Springs	Freeland	39	1958
8/14 - 20R1	Low Wm. Spr.	Heath	34	1958
9/12 - 10L1	Dry Creek	Scott (dry) 1/	580	1945
9/12 - 10R1	Dry Creek	Scott	101	1945
9/13 - 30	Mecca	Village Cafe	40 (est.)	1956 (est.)
11/12 - 18P1	Metolius Bench	Estabrook	370	1958

1/ The first Scott well, a dry hole, was drilled within one and one-half miles of the former dry hole drilled in 1935, Johnson #3.

9-2.10 The nine drilled wells described in paragraph 9-1.9 were drilled by local driller, Mr. Bert Abrams, or Mr. Lawerance Kowaleski. Both of these drillers use cable-tool or percussion equipment. Mr. Abrams is reported to be the only driller currently using well development practices as described in paragraph 4-4.17. The wells which he has drilled or redrilled on the reservation are reported (1) to have acquifers generally not suited to development practices. For this reason, no wells on the reservation are known to have been developed for purposes of increasing yield. Subsequent silting at the Wewa and Island well, indicates silt removal by development may be advisable.

9-2.11 Well Failures - Dry Holes. Records and well logs indicate that there have been two dry holes drilled on the reservation, both being in the Dry Creek Area. Well schedules, compiled from existing data at the Agency and from field observations by Newcomb (83) indicate that both the Johnson #3 well of 1935 and the first Scott well of 1945 were drilled to depths below 550 feet without striking water. See wells 9/12 - 23A1, and 9/12 - 10L1.

9-2.12 Tabulation of Wells on Reservation. A tabulation of wells on the reservation, with well log information currently available, is listed in Appendix IX-A. The tabulation is from files of the Office File Report no.344.22 of the Agency Land Operations Office (82), and Well Schedules recorded on U. S. G. S. Form 9-185 by Newcomb and Hogenson of the Water Resources Division of the U. S. Geological Survey, Portland (83). The locations of these wells are plotted on map of Appendix VIII-B.

Section 9-3: Well Logs and Performance Records.

9-3.1 Driller's Logs. Driller's logs of wells constructed on the reservation have been nearly always inadequately completed. The failure for a complete drilling log to be recorded at the time of drilling and filed in public records is unfortunate. The valuable information of the sub-surface geology, that can be so easily obtained and recorded at no extra cost at the time of drilling, is forever lost if the driller neglects to take the time to make and record the few important observations.

9-3.2 Fortunately, drillers in the recent years appear to be more aware of the importance of drilling logs, and have taken the time to record this information in greater detail. However, for the deep wells drilled in 1935 there is scarcely any stratigraphic information. Information from drilling logs is tabulated in Appendix IX-A.

9-3.3 Well Performance Records. There appears to have been no well performance records maintained for any wells drilled on the reservation. For only one well, the Suppah well, is the sustained yield known, even approximately. Data on drawdown, seasonal fluctuations of the water-table, perched water zones, or other important hydraulic characteristics are practically unknown for the deep wells. Between 1953 and 1956, Mr. Newcomb (83) of Water Resources Division of U. W. Geological Survey, Portland, compiled well schedules using data from Mr. Morfit of Bureau of Public Health and from field measurements.

9-3.4 Little can be done to replace missing drilling data from wells already completed. It is recommended that at all wells drilled on the reservation in the future that complete well drilling logs be recorded by the driller, and copies of the logs be kept in office files at the Agency.

Section 9-4: Drilling Equipment and Development

9-4.1 Drilling Equipment. The dug wells have been finished with timber or rubble masonry curbing, and more recently by installation of concrete pipe secions. An example of the latter is the Wolf well, cased with twenty-four inch concrete pipe sections. The Mission well at Simnasho, dug and curbed with rubble masonry to a depth of thirty-five feet, is apparently the deepest dug well on the reservation. At present the well is inoperative, due to pollution.

9-4.2 Cable-tool drilling equipment has been exclusively used for drilled wells on the reservation. Although accurate stratigraphic sampling and static water level observations are possible during the construction of percussion drilled wells, this opportunity for securing valuable geologic data has usually been ignored on the reservation.

9-4.3 Casing. The deep formations on the reservation are usually sufficiently consolidated to allow uncased holes. Where the formations are tight and consolidated, only the surface mantle and gravel conglomerates are cased. Deep wells penetrating consolidated formations are generally cased for only the first twenty to thirty feet required for a sanitary seal.

9-4.4 The John Day tuffs are usually sufficiently consolidated to require no casing. Clarno tuffs and Columbia River basalt require no casing. The Dalles formation may or may not require casing, depending upon the nature of the gravel members. Full casing is usually required where gravel is found below the water-table.

9-4.5 Grouting. The grouting of uncased holes is common in this area. The grouting of a hole is performed by pouring cement into an uncased hole, allowing the cement slurry to penetrate the interstices of the formation. The cement in the interstices hardens as the drilling continues. Grouting an uncased hole serves to stabilize the material adjacent to the hole. Cave-ins of uncased holes are minimized. Grouting is especially beneficial where submersible pumps are used, as a cave-in above a submersible pump usually prevents recovery of the pump.

9-4.6 Grouting helps prevent the loss of perched water. Because wells on the reservation are thought to often yield perched water, grouting of the uncased holes may be helpful for obtaining maximum discharge.

9-4.7 Well Development. None of the approved well development practices described in paragraph 4-4.17 have been used on wells drilled on the reservation. At the present time only one driller (1) in the Madras area is reported to employ well development techniques. Wells drilled on the reservation by this driller, Mr. Bert Abrams, are reported to have generally yielded water from formations too consolidated to respond to well development.

9-4.8 It is reported that most wells on the reservation would probably be not improved by development. Development is beneficial only to sedimentary or other granular formations. However, examination of drilling logs having stratigraphic sampling, and observations of exposed topography at canyon faces indicates that many of the wells obtain water from the Dalles sediments which may respond favorably to development.

9-4.9 Three wells which are thought possible of being improved by development are the Island well, the Hoptowit well on Miller Flat, and the Wewa well on the Metolius bench. The Hoptowit well is now reported to have "lots of water" which it receives from the Dalles formation. Although the Dalles sediments at this well now yield water sufficient for present duty, an inspection of outcropped Dalles three miles to the west at Boulder Creek near Boulder Corral, indicates the deeper formation may be capable of incresed flow following development. The Wewa well has silted in two times and is now inoperative. The Island well has been subject to continuous silting, the temporary corrective action taken has been to raise the cylinder. At the present time, 1960, the Island well is inoperative. It is probable that the latter two wells would respond to development. Removal of the fine material adjacent to the hole would have the effect of reducing inflow water velocities at the casing. Reduced velocities at the casing would result in less sediment displacement and improved well performance.

9-4.10 Drilling Costs. Drilling costs on the reservation are currently approximately $6.00 per linear foot of six inch diameter well. Practically all drilled wells in this area are six inch diameter. The approximate price of $6.00 per foot includes steel casing for about twenty percent of the depth of the hole.

9-4.11 An estimate of total monthly operating costs of a six inch by five hundred foot well equipped with electric driven pump with assumed indefinite term of usefulness for well and 25 year life of pump is:

Power.	$ 1.50
Maintenance and repair.	2.00
Capital recovery at 5% for $1,000.00 pump and service installation having no salvage value at end of twenty-five years.	6.00
Interest at 5% for $3,000.00 drilled well.	12.50
Total monthly operating costs	$ 22.00

Section 9-5: Well Operation and Maintenance.

9-5.1 Power. The existing deep wells are used primarily for stock water, and are operated by windmill driven piston pumps. Winds blow quite steadily across the plateaus of the reservation. While electrically operated pumps may be more convenient in their operation, wind driven pumps have been reasonably satisfactory. It will probably be many years before the wind driven pumps can be replaced with electrical units, for it appears unlikely that utility electrical service will be extensively installed throughout the reservation in the near future.

9-5.2 The lack of electric utility service on the reservation appears to be a part of the cause of social-economic patterns having a greater deterrent to development of ground water by wells than do the direct problems of operating wells without electricity. Social patterns resulting from a sound agricultural environment, good all-weather roads, good communication facilities, and availability of electrical service for household use appear to have far greater importance than do problems associated with obtaining power for well pumps. While electrical power is desirable for development of ground water, its availability is not imperative.

9-5.3 From the standpoint of total overall development of water resources of the reservation, problems of irrigation and treating surface waters for human consumption appear more directly effected by the availability of electric service. The application of electric service to water treatment is discussed in paragraph 10-6.16.

9-5.4 Maintenance. Although operation and maintenance of the various deep wells are reported to be the responsibility of the users, it appears that very little effort is directed toward systematic maintenance. Repairs to the windmills and pumps are reportedly performed by personnel of the Agency Land Operations Office. Many of the objections of the wind driven pumps directed toward their unreliability could undoubtedly be corrected by a systematic program of preventive maintenance.

9-5.5 There are at present no observations made of well performance. Performance records of existing wells are invaluable for planning future well developments. It is suggested that well performance measurements be obtained periodically by personnel of the Agency Land Operations Office. Such a program would serve a dual purpose of (1) supplying useful information for improved planning of ground water utilization on the reservation, and (2) improving well and pump preventive maintenance.

Section 9-6: Hydrology of Wells on the Reservation.

9-6.1 Free and Confined Water. It appears unlikely that confined water subject to hydro-static pressure exists within practical drilling depths on the reservation. Bert Abrams, a driller from Madras who has drilled wells on the reservation, reports (1) no evidence of any artesian conditions. If artesian conditions are present, it would be most likely to occur in the Columbia River Basalt or in the Dalles formation. The Range Report of 1937 (79, p. 18) discusses the possibility of artesian water in these formations: "It would require very careful investigation to locate favorable sites." There is at present no evidence to support the theory that they do exist.

9-6.2 Perched Water. It is the belief of many persons familiar with the ground water situation on the reservation, that many of the wells yield water from perched sources. Abrams (1) reports that most deep wells on the reservation that tap the Dalles sediments yield perched water that would eventually find its way to contact springs at lower elevations. From this, Abrams concludes that the only advantage a drilled well has over the existing springs is in point of water delivery, and that a drilled well on the reservation in general will not supply water in greater amounts than received from the existing springs which lie at lower elevations.

9-6.3 Subsurface Geology. Data from driller's logs of wells drilled on the reservation are so incomplete that only meager information is available. From the generally small discharge received from the deep wells, it is apparent that the deeper formations are quite impermeable and dense. Wells on the reservation penetrate a wide range of materials, having both a uniform and non-uniform distribution. Formations vary widely within a small area. The Tootick well is dug in a clay formation for nearly its full depth, while the Suppah well, not two miles away, penetrated rock for its full depth.

9-6.4 The Water-Table. The location of the water-table is generally not known on the reservation. If many of the wells draw upon perched water, see paragraph 9-5.2, the true water-table than lies below some of the wells drilled upon the reservation. Because of the deeply eroded topography of the eastern part of the reservation, the water-table is necessarily deeply depressed below the level of the plateaus. The gradient of the water-table on the reservation is not known. Stearns (53, p. 10) reports the slope of the water-table east of the Deschutes River adjacent to the reservation to be approximately 100 feet per mile, the water-table sloping downward towards the effluent river.

9-6.5 The lack of a well defined water-table in the tight formations of this part of the state is discussed in other reports. Stearns reports the absence of a clearly defined water-table in the Clarno formation. See paragraph 7-4.3. Abrams (1) reports core holes sunk into the John Day tuffs to depths below the adjacent Deschutes River surface that failed to display a water-table surface. The tuffs act as a tight impermeable barrier that effectively stops downward percolation of water. It is possible that water reported by drillers as perched water in the Dalles sediments near the upper contact of the John Day is true free ground water. The water-table on the reservation appears to be so poorly defined, that drillers have been generally unable to establish its position during drilling operations. For this reason it is difficult to determine from drilling logs if the major streams of the reservation are effluent or influent. Run-off measurements of the Warm Springs River show this stream to be gaining, and would therefore have a water-table gradient sloping downward toward the stream surface. The same would appear likely for the other deeply eroded portions of streams, such as Beaver Creek, lower Mill Creek and Shitike Creek.

9-6.6 Interference. Because of the general impermeable character of formations yielding water on the reservation, the radius of well influence can be expected to be small. Where wells are located more or less at right angles to the direction of underground water flow, the underground water flow being generally at right angles to direction of deeply eroded perennial drainage, it is improbable that interference would occur with wells spaced 1000 to 2000 feet apart. At present, the only location on the reservation where well interference appears a potential problem is at Schoolie Flat, this occurring only with ill advised well location.

Section 9-7: Duty and Quality.

9-7.1 Duty. Wells on the reservation yield water in rates of discharge that limits their use to domestic, stock and small garden irrigation. The only wells on the reservation supplying water at rates in excess of these minimum needs are the wells located in alluvium adjacent to perennial streams.

9-7.2 Quality. The deep wells of the reservation yield soft water. Water from the deep Dalles sediments and from the top formations of the John Day formations are soft. Often the shallow wells yield harder water than do the deep wells, due to surface alkali patches. Hardness or turbidity of ground water from wells on the reservation has not been a problem.

9-7.3 Of great concern to the health of the residents of the reservation is present use of polluted water for domestic purposes. A report by Division of Indian Health (69, p. 20) indicates that 34 percent of the people on the reservation use unapproved water. Approximately 55 percent of the residents live within a one-mile radius of the Agency, most having access to the water from the distribution system serving the Agency. This means that very few of the residents living apart from the Agency use water from approved sources. Of 14 wells investigated, 8 were found to yield unsafe water. Appendix IX-B is a tabulation from this survey showing adequacy of existing water supply on the reservation.

9-7.4 The Division of Indian Health (69, p. 24) estimates that it would cost $43,800 to provide the minimum facilities for safe water supplies for Indian homes on the reservation. The estimate is tabulated:

New wells, 42 @ $1000	$42,000
Renovation of existing wells, 9 @ $100	900
Development of springs, 6 @ $150	900
TOTAL	$43,800

9-7.5 The estimated cost of $1000 of drilling a new well would be sufficient to drill and install a pump in wells being of approximately 100 feet or less in depth. Whether 42 proposed wells on the reservation would be of an average depth shallow enough to develop for an average cost of $1000 each is in question. Recently drilled wells in alluvium or in less favorable locations on the reservation indicate that extensive well development costs may average more than $1000 per well.

9-7.6 The need to develop sources of safe domestic water, be it from springs, wells or surface developments is undoubtedly the most urgent water problem on the reservation today. Ten percent of the 232 communicable disease cases reported to the Division of Indian Health (69, p. 13) in 1957 was hepatitis, a disease often associated with polluted water. Problems relating to water pollution are also discussed in paragraphs 8-4.3, and 10-6.1.

Section 9-8: Schoolie Flat.

9-8.1 Land Forms and Drainage. The topography of Schoolie Flat is characterized by three prominent features, the maturely eroded Mutton Mountains to the east, the youthfully dissected lava plain forming most of the area, and the deeply eroded canyon of Beaver Creek and Warm Springs River to the west and south respectively. The altitude of the plain ranges from 2900 feet to about 2400 feet. The canyon floor to the west and south is from 500 feet to 900 feet below the elevation of the plain.

9-8.2 Stratigraphy. The principal formations of the area are the Clarno formation which constitute the Mutton Mountains, the John Day tuffs and ash which are exposed adjacent to Quartz Creek and Warm Springs River, and the Dalles formation which is exposed over much of the plain. See Appendix VII-B. Recent alluvium appears on the Schoolie Flat. The nature of these deposits and the occurrence of water within them is discussed in detail in sections 7:1 and 7:4.

9-8.3 Existing Wells. Three drilled wells are within Schoolie Flat. These are the Simnasho well, the Suppah well, and the Tootick well. Four shallow dug wells are known within Schoolie Flat. These are the Mission well at Simnasho, a 20 foot unnamed rubble or concrete curbed well near the racetrack at Simnasho, the Wolf well and the Calica well.

9-8.4 The Simnasho well, 7/12 - 7F1, is a six inch well 565 feet deep. It is drilled entirely in the Clarno formation. It is reported to have a static water level 430 feet below the land surface, and to yield ten gallons per minute with a 19 foot drawdown. Duration of pumping test is not known. The well is used to supply domestic and stock water in the settlement of Simnasho. It is considered one of the better deep wells on the reservation.

9-8.5 The Suppah well, 7/12 - 34L1, is a six inch well 300 feet deep. It is drilled entirely in rock near the westerly extremity of the Clarno formation. It is reported to have a static water level only 87 feet below the land surface, and to yield two gallons per minute for sustained pumping, or to yield four gallons per minute for short periods. The well apparently discharges perched water. See Appendix IX-C.

9-8.6 The Tootick well, 8/12 - 4R1, is a six inch well 370 feet deep. It is drilled in vesicular lava rock, tuffs, sandstone and gravel. It is reported to have a static water level 260 feet below the land surface, and to yield 20 gallons per minute with a test bailer. Duration of the test is not known. The driller reports that at the time of drilling water stood in the well 152 feet below the land surface. It is likely that the well discharges perched water.

9-8.7 The Mission Well, 7/12 - 7F2, at Simnasho is a hand dug shallow well of 35 feet depth. This well, dug before 1920 and curbed with concrete and rubble to a diameter of four feet, is now inoperative due to contamination. The well is reported to penetrate sedimentary deposits. No discharge data is known, but it is reported to have been a strong well.

9-8.8 A shallow well located about a mile south of Simnasho, described by Geologic Survey Subdivision at 7/12 - 17N1, is used for domestic purposes. The well is about 20 feet deep, curbed with concrete or rubble masonry, and is fitted with a hand pump which lifts water from about 10 to 15 feet below the ground surface. Discharge is good, but the water is reported to be polluted.

9-8.9 The Wolf well, 7/12 - 21A1, is a 12 foot hole curbed with 24-inch concrete pipe sections. The well is dug into sedimentary deposits at the western toe of the Mutton Mountains, and appears to yield water that would eventually emerge from springs at adjacent lower topography.

9-8.10 The Calica well, 8/12 - 9A1, is a 10 foot hole, located in natural drainage at the toe of the Mutton Mountains. The well is essentially a spring development. Its capacity is sufficient for domestic needs.

9-8.11 Occurrence of Ground Water. Rock formations that may yield a minimum of 10 gallons per minute are practically restricted to the Clarno, Dalles formations and recent alluvium. The general ability for these formations to yield water is discussed in section 7-4.

9-8.12 Schoolie Flat and adjoining topography has been subject to alluvium from the higher Clarno formations. In most places the alluvium is made of gravel and boulders of the Clarno formation and lavas of more recent vulcanism resulting in a matrix of silt and clay from the John Day and Dalles formations. The high proportions of fine-grained materials would prevent this alluvium from yielding water readily in most places. However, in the canyon of Coyote Creek the alluvium appears to contain sufficient coarse-grained material that shallow wells or infiltration galleries might obtain water in desired quantities. Newcomb (40, p. 10) suggests one of these places is near the gravelly bar at the confluence of Coyote and Beaver Creeks in section 14, T. 7S., R. 11E.

9-8.13 Newcomb (40, p.5) reports the beds of the Dalles formation appear to dip below the level of Beaver Creek where that creek canyon borders the northerly half of the west side of Schoolie Flat, section 30, T. 7S., R. 12E. In that situation the Dalles could be expected to be charged with ground water, and, if sufficiently permeable strata exist, it would yield water in desired quantities.

9-8.14 Indications are that some of the deep wells on Schoolie Flat may yield water from perched sources. Geologically, the Schoolie Flat lies favorable for perched water which enters the ground at the Mutton

Mountains to the east. Ancient subsurface alluvial deposits from the Mutton Mountains probably are interbedded in impermeable formations that support perched water. Newcomb (40, p. 11) suggests two locations for suggested exploration for perched water supplies within 300 or 400 feet of the surface. The generally favorable locations appear to be:

I. In the northeast corner of section 4, T. 8S., R. 12E.
II. In a linear area extending through the northwest and southeast corners of section 30, T. 7S., R. 12E.

<u>9-8.15 A Ground Water Distribution System for Schoolie Flat and Vicinity.</u> Henderson (21) presents a plan for the distribution of ground water through a distribution system to serve the Schoolie Flat, Simnasho, the Island and Quartz Creek area. The report is found in full at Appendix IX-F.1 and IX-F.2. The plan utilizes the proposed well locations at the mouth of Coyote Creek suggested by Newcomb and Hogenson (40), see Appendix IX-E. The plan is based on an anticipated 240,000 gallons per day demand to serve 150 families in this area. Henderson estimates a total installation cost of $450,000 for the system, suggesting a 25 to 50 year serviceable life. A monthly operational cost for the system may be expected to approximate the following:

Power, $0.015/kw.hr. (includes power line construction and demand charges)	$ 340.00
System maintenance and repair (¼% installed cost)	1,120.00
Monthly capital recovery at 5% for $420,000.00 (power line cost deducted) having to salvage value at end of 40 years	2,040.00
Total estimated monthly operation cost	$ 3,500.00

<u>9-8.16</u> On the basis of the above estimate, with the system operating at design capacity, the monthly cost per farmstead would be approximately $23.00. The system delivering water from wells at Coyote Creek would perform similar service to Schoolie Flat as a pumping site pumping directly from Beaver Creek, as described in paragraph 10-5.8. Monthly costs per family for service from either system when operating at design capacity are approximately equal. It does seem that an expected demand of 150 families for this combined area is more than can be expected, particularly if the Schoolie Flat area remains under dry land farming. The conclusion drawn by Henderson, see Appendix IX-F.1 sub-title U. S. Geological Survey Report, " . . . . they stated, unequivocally, that any attempt to supply domestic water from either the underground or surface supply within Schoolie Flat area, based on present demand, would be fruitless." This interpretation of Newcomb's and Hogenson's report (Appendix IX-E) appears to be unjustifiably pessimistic. While no single well on the plateau of the Flat could support a distribution system, the possibility of construction of independent wells at farmsteads should not be discounted.

9-8.17 If an irrigation unit is to be constructed at Schoolie Flat, the expected demand of 40 farmsteads for Schoolie Flat (see paragraph 10-5.8), or the expected demand of 150 family units at the combined area of the Island, Simnasho, Quartz Creek and Schoolie Flat (see paragraph 9-8.15) is probable. However, in the event of irrigation construction in this area, a satisfactory source of domestic water would be available from properly protected irrigation ditches and individual automatic treatment facilities, at a more favorable cost to a user. See paragraph 11-13.29.

9-8.18 Ground water for a distribution system to solely serve the expanding population at Simnasho appears to be the most readily available from a proposed well located at the mouth of Coyote Creek, the location described by Newcomb and Hogenson (40), and Henderson (21). For such a system, having a four inch transite pipe buried adjacent to the road between the well and Simnasho, construction costs could be kept to a minimum. Approximately three miles of main line would be required. A pump delivering 1500 gallons daily to 40 homes at Simnasho would have a capacity of 125 gallons per minute if operating eight hours per day. Required pump horsepower at 75 percent hydraulic efficiency to deliver water to a reservoir providing adequate distribution pressure would be approximately 16 horsepower.

Estimated installed costs (labor and material):

Power line construction	Included in hourly rate.
Pump motor and building	$ 4,000.00
Electrical control system	4,000.00
Main line	
4" x 16,000' transite @ $2.00	32,000.00
2" x 2,000' steel @ $1.00	2,000.00
1" x 2,000' steel @ $0.70	1,400.00
Reservoir, 80,000 gal. effective cap., covered, chlorinator	9,000.00
Total estimated installed cost	$ 52,400.00

Estimated monthly operating costs:

Power, $0.015/kw.hr. (includes power line construction and demand charges)	$ 50.00
System maintenance and repair (¼% installed cost)	105.00
Monthly capital recover at 5% for a $52,400.00 investment having no salvage value at end of 40 years	250.00
Total estimated monthly operation cost	$ 405.00

9-8.19 On the basis of the above estimate, a distribution system supplying ground water to Simnasho, operating at a design capacity of 40 homes, would cost approximately $10.00 per month per home. Because design capacity of the four inch main line is conservative, and nearly 90 percent of the monthly cost in the system as described is fixed cost, the system could carry heavier loads at a corresponding reduction in unit costs to the water user.

9-8.20 Conclusions. The history of drilled wells on Schoolie Flat has in general been sufficiently satisfactory to encourage further development. The geology of the area gives evidence of additional sources of water, either ground or perched water. Because Schoolie Flat appears at the present time to become one of the more developed rural areas of the reservation, a dependable source of domestic and stock water is important. Although eastern portions of the Flat may be better served by springs, ground water development by deep wells appears more economical and to offer a more dependable supply for areas farther removed from the existing springs.

9-8.21 Wells in this area probably would seldom exceed depths of 500 feet. Only one well exists on Schoolie Flat deeper than 500 feet, the average of the existing drilled wells being 365 feet. Drilling costs based on average depth of existing wells would be about $2200.00 per well, including casing. Wells on Schoolie Flat would probably not be subjected adversely to interference from adjoining wells, provided wells are located at projected spacing parallel to Beaver Creek and Warm Springs River at distances not less than 1000 feet. Capacity of existing wells on Schoolie Flat indicates anticipated discharges from one well generally sufficient for requirements of two or three farmsteads. Such a plan would require intermediate water-tank storage. A well, jointly used by several farm units and centrally located, would provide safe domestic water at unit costs for development more favorable than other plans previously discussed.

9-8.22 A well located near the confluence of Coyote Creek would probably be a strong well, sufficient for a source of domestic water to both Simnasho and to Schoolie Flat. However, if agriculture at Schoolie Flat continues to be dry farming, it is unlikely that the population on the Flat will increase sufficiently to justify the expense of an extensive distribution system. A distribution system to Simnasho from a well at Coyote Creek appears feasible, and to be preferred to any other ground or surface water development system.

9-8.23 It is advisable, before additonal wells are drilled on Schoolie Flat, to obtain complete performance records of the existing wells. This should include static water level, sustained pumping capacity, and drawdown. Every additional well drilled on the Flat should have an accurate and complete drilling log, along with adequate performance records. Although good well records are a valuable asset in a ground water study at any location, they have special value where ground water development is extensive, as may be the case at Schoolie Flat. Suggested well locations outlined in paragraph 9-8.12 are those that appear most feasible at the present time. Additional information from newly drilled wells may suggest development more favorably located to serve existing or proposed farmsteads.

Section 9-9: Sidwalder Flat.

9-9.1 Land Forms and Drainage. The topography of Sidwalder Flat is characterized by Sidwalder Butte on the west, and the lava plain which is bounded on the north, east and south sides by Hehe Butte, Warm Springs River, and Mill Creek, respectively. The plain has a thin and rocky soil from the Dalles formation, and is devoid of deeply eroded drainage patterns. Very few springs appear on Sidwalder Flat. Because of the Mill Creek Irrigation Unit, which is kept in partial operation during most of the year, Sidwalder Flat has more surface water than any other portion of the reservation. The general abundance of surface water on the reservation has resulted in its use for both domestic and stock purposes.

9-9.2 Stratigraphy. Hehe Butte and Sidwalder Butte are two remnants of Cascan vulcanism. The plain is overlain with soils of the Dalles formation. Sources of ground water are expected to be from the Dalles formation, or from the poorly defined contact with the underlying John Day beds. Although it is possible that the porous Cascan lavas from Hehe Butte and Sidwalder Butte may have filled pre-existing drainages, and be in a position to be charged with ground water, there is no evidence today that indicates their location.

9-9.3 Existing Wells. One drilled well exists on Sidwalder Flat. The Sidwalder well, 8/11 - 6L1, is a six inch well drilled to a depth of 407 feet. There is no information available concerning formations penetrated, nor is any well performance data available. The well has been used for stock, although during the summer of 1959 it was inoperative, presumably due to mechanical failure of the pump. This well has apparently yielded water in sufficient quantities for stock. Its continued operation for stock water is not required because of available surface water from the irrigation unit.

9-9.4 Occurrence of Ground Water. The location of the water-table on Sidwalder Flat is not known. The well penetrates to a depth about 100 feet below the elevation of Warm Springs River which is about five miles to the east. It is likely that numerous ground water mounds, see paragraph 2-7.10, exist on Sidwalder Flat as a result of the practice of maintaining water more or less continuously the year round in the irrigation ditches. Sidwalder Flat now suffers some from poor drainage, surface water becoming perched on the numerous impermeable members of the Dalles formation. Such conditions are favorable for shallow wells that receive recharge water from the irrigation unit.

9-9.5 From considerations of both topography and geology ground water on Sidwalder Flat appears to be reasonably available. The upper contact of the John Day beds at a general elevation of about 2100 feet above sea level is an indication of the maximum depth to which wells would be required. The Flat is large in area, not bounded by as deeply eroded canyons as many of the plateau regions of the reservation. The entire westerly edge of the Flat, being unbroken in terrain to the easterly toe of Sidwalder Butte is available for ground water recharge.

9-9.6 Wells drilled on Sidwalder Flat would apparently draw upon waters from the Dalles formation. This formation appears variable in its permeability, the success of wells drilled on Sidwalder Flat could be expected to depend upon the extent and location of the permeable members. There is at the present time insufficient stratigraphic data to predict the locations of favorable subsurface formations. The one existing well on Sidwalder Flat, although now in disuse, appears to have been satisfactory for domestic and stock requirements. It is expected that deep wells in the generally even topography of Sidwalder Flat would be approximately equal in depth to that of the existing Sidwalder well, being around 400 feet.

9-9.7 Conclusions. There are two sources of water for domestic purposes at Sidwalder Flat, either surface waters or ground waters. The water from the shallow wells may be thought of as surface waters, for they are often merely collecting basins for the water filtering downward from the irrigation structures of the Mill Creek unit. With proper sanitation control, water from this source could satisfactorily serve the domestic requirements for Sidwalder Flat. The use of treated surface waters for domestic needs is discussed in detail in Chapter 10.

9-9.8 Deep wells in Sidwalder Flat could be expected to have yields satisfactory for stock or domestic consumption. Because of abundant surface water on the Flat, the duty of ground water is practically limited to domestic needs. Well depths in this area could be expected to approximate the 400 foot well now known as the Sidwalder Well. Wells in the southeastern portion of the Flat may be somewhat deeper than elsewhere. Such deep wells having a sanitary seal would have the advantage of offering domestic water safe to use when untreated. The cost of drilling a deep well in this location would greatly exceed that required to develop a source of treated surface water.

9-9.9 The conclusion is made, that while deep drilled wells on Sidwalder Flat could be expected to provide amounts of water necessary for domestic needs, where surface waters are available the development of treated surface water would be economical and satisfactory. While water can be obtained in many places on the Flat from shallow wells, water from these sources should be considered as surface water, and be given biological treatment. At the present time, the lack of central electric utility service on Sidwalder Flat prohibits the use of automatic water treatment devices such as the small hypochlorinators now commercially made for rural installations.

9-9.10 Prior to any proposed deep well drilling on Sidwalder Flat, performance records should be obtained on the existing well. Wells spaced at intervals not less than 1000 feet in a generally projected north-south direction will probably not suffer from interference. Every additional well drilled on Sidwalder Flat should have an accurate and complete drilling log, and performance record.

Section 9-10: The Island

9-10.1 Land Forms and Drainage. Topographically the Island is situated unfavorably for the occurrence of ground water. No point on the Island is greater than approximately one mile from a deeply cut canyon. The terrain of the Island is generally level and unbroken. The floor of the steep-walled canyons that border all but a short portion of the north side lie at an average elevation 500 feet below the level of the plateau. Beaver Creek, forming the east boundary of the Island, is eroded to greater depths than is the Warm Springs River on the west.

9-10.2 Stratigraphy. The canyon walls of the Island appear to be comprised mainly of lava rock. The lava, being the basaltic members of the Dalles formation, appears to be only sparingly interbedded with sedimentary material. Newcomb and Hogenson (40, p.9) report the 500 foot deep Island well as probably penetrating lava and sediments of the Dalles formation, and possibly entering the John Day formation near the bottom of the hole. All indications show that at the deep depths where ground water is possible, the formations are generally tight and quite impermeable.

9-10.3 Existing Wells. One well exists on the Island, 7/11 - 36M1, a well drilled to a depth of 500 feet in 1935. The well is cased with a six inch casing to a depth of 350 feet. A drilling log is not available. The well has been used to supply stock water. Until continual silting caused the well to be inoperative, the well has been reported to have a small discharge, but to be reliable and adequate for stock water. Periodically, the cylinder at this well has been raised, giving temporary relief from the silting problem. Today the cylinder is apparently so high in the well that it fails to pump usable amounts of water. Newcomb and Hogenson (40,p.9) report that the driller, an employee of the R.J. Strasser Drilling Company, observed that the water was obtained below the lava rock during drilling operations. The static water level was observed at the time of drilling to be low in the well, and the water level drew down greatly with a small amount of bailing. The continual silting at this well suggests well development to remove the fines near the casing.

9-10.4 Occurrence of Ground Water. Water in the existing Island well is apparently found at approximately the elevation of the adjacent Beaver Creek which lies to the east. Warm Springs River lying to the west flows at a steeper gradient, and in most places appears to flow at a higher elevation than does Beaver Creek. It is possible that wells drilled near the west edge of the Island will encounter ground water at slightly higher elevations than wells drilled closer to the east edge. The rapid drawdown reported to occur with small pumping at the existing Island well would be probably characteristic of most wells drilled on the Island.

9-10.5 Conclusions. Ground water development on the Island is limited to that which may be obtained from deep wells. Wells on the Island probably will require depths comparable to the existing 500 foot well. At locations north of the north line of township eight, wells drilled near the west side of the plateau may encounter water at slightly shallower depths, provided the subsurface formation is sufficiently permeable. It appears unlikely that wells can be obtained on the Island that exceed the bare minimum requirements for domestic or stock requirements.

Section 9-11: Miller Flat.

9-11.1 Land Forms and Drainage. Miller Flat has a generally level and unbroken terrain that is bordered on the north, east, and south sides by deeply eroded stream patterns. The lower reaches of Mill Creek, Warm Springs River, Shitike Creek and west of the edge of the Dry Creek valley form deeply depressed boundaries of Miller Flat. Only the western edge of Miller Flat is directly open to uplands. Boulder Creek, forming the northwesterly boundary of Miller Flat, flows out on the surface of the plateau in a shallow stream bed. Interior drainage patterns on the plateau are irregular and shallow.

9-11.2 Stratigraphy. Exposed geology in the canyons of Warm Springs River, Shitike Creek and the western edge of the Dry Creek basin indicates that the lower contact of the Dalles formation with the underlying John Day formation occurs at an elevation between 2000 and 2100 feet above sea level. Although the Dalles formation appears consolidated, it probably is sufficiently permeable to produce yields to wells for requirements of domestic or stock use. The John Day formation is expected to be so tight and impermeable to be of little value as an aquifer. Except, in the portions of Miller Flat close to the Warm Springs River, Shitike Creek and along the easterly edge of the Flat, the water-table on Miller Flat is probably contained in the Dalles formation.

9-11.3 Existing Wells. The one drilled well on Miller Flat, 8/11-35P1, (in some reports described as 8/11 - 34 R1) was drilled to a depth of 320 feet in 1935. The first twenty feet is cased with a six inch pipe. The hole is entirely within Dalles deposits. The driller's log report the first 248 feet to be cemented gravel, and the remaining porting to be Dalles (Madras). The formation penetrated appears to be sufficiently consolidated to not require casing. The driller, R.J. Strasser of Portland, reported a static level at 208 feet below the ground surface at the time of drilling. No known performance tests have been made. The driller reported "lots of water," measuring ten feet of drawdown after several hours of hard bailing. It is used for stock water.

9-11.4 The Miller Flat well is one of the better deep wells on the reservation. The well penetrates sufficiently below the water table into an aquifer having permeability to allow it to be one of the stronger wells. No data is available on static water level in recent years, it is probably substantially the same as reported at the time of drilling. Newcomb and Hogenson (83) attempted in 1956 to measure the static level, but failed to remove the bolted flange capping the casing.

9-11.5 Occurrence of Ground Water. Warm Springs River and Shitike Creek are apparently effluent streams where they border Miller Flat.

Mill Creek is probably influent upstream from a point three or four miles from its confluence with Warm Springs River. Ground water at the plateau portions of Miller Flat near these effluent streams is expected to be found at deep depths. Such wells could be poor producers, for in these regions the water-table is probably found in tight mixutre of John Day and Dalles deposits.

9-11.6 If the streams described above are effluent, it is expected that the water-table gradient is generally normal to these streams. In this event the water-table is probably more deeply depressed towards the easterly portion of the Flat and towards the effluent streams. Extensive impermeable beds at relatively shallow depths in the Dalles formation could prevent the downward percolation of water, and retain considerable amounts of perched water close to the ground surface at locations close to the deeply eroded effluent streams. Such appears to happen at the Stacona spring, 9/11 - 11F, a spring being about a mile and a half south of the Miller Well and also being near the canyon wall to Shitike Creek.

9-11.7 Deeply eroded drainage on three sides of Miller Flat, and the presence of deep covering formation having a more or less favorable degree of permeability, suggests that wells located in the "interior" portions or the westerly portions of Miller Flat would meet with greatest success. This is partially substantiated by the reported good performance of the existing Miller Flat well, where water stands 208 feet below the ground surface. That the aquifer here is permeable is witnessed by the reportedly small amount of drawdown accompanying sustained bailing. Further to the west, in the vicinity of Boulder Corral, the exposed geology at the drainage of Boulder Creek shows sedimentary material that would be highly favorable for ground water development, provided the material extends downward to the water table.

9-11.8 Conclusions. The existing Miller Flat well is one of the better deep drilled wells on the reservation. The well has never been satisfactorily tested to accurately determine its performance. Although the well is uncased, the consolidated formations appear to be sufficiently permeable to yield a good sustained flow with a small amount of drawdown. The well has one of the highest reported static water levels of any of the "plateau"wells on the reservation.

9-11.9 Future development of ground water on Miller Flat appears to be generally limited to deep wells. Topography and geology favor well locations toward the western portion and those areas of the plateau removed from the deeply eroded effluent streams. The existing Miller Flat well, centrally located on the plateau, reportedly draws from approximately one hundred foot of aquifer in the Dalles formation. Other wells generally confined to the central east-west two mile portion lying within Range eleven would probably have performances comparable to the existing Miller Flat well. Interference would appear to be most critical on wells closely spaced along an east-west axis. Because of occurrence of favorable aquifers, discharge from wells would be satisfactory.

9-11.10 Prior to further ground water development on Miller Flat, it is advisable to adequately performance test the existing well. Information from such a test would be helpful in the hydrology analysis of the area, and would enable design for more complete utilization of present facilities. Every additional well drilled on Miller Flat should have an accurate and complete drilling log and performance test.

Section 9-12: Dry Creek.

9-12.1 Land Forms and Drainage. The Dry Creek basin consists of an area of about eight square miles at or below an elevation of 1700 feet above sea level. Severely eroded hills surround the basin. Drainage is generally west to east, Dry Creek flowing intermittently off Miller Flat into the Deschutes River. A considerable number of springs emerge from Clarno, Columbia River Basalt, and Dalles deposits at the edge of the basinal area. They flow out onto the John Day near its upper contact with the overlying deposits. Dry Creek flows only during rainfall periods.

9-12.2 Stratigraphy. The basinal portion of Dry Creek is of the John Day formation. The tight ash and tuffs of the John Day are everywhere exposed at the lower elevations. The John Day beds form an impermeable basement to the valley. Their depth is not known. Overlying the John Day at the higher elevations are the Clarno formation, the Columbia River basalt, and The Dalles deposits. All display greater permeability than do the tuffs of the John Day.

9-12.3 Existing Wells. Available records of wells drilled in the Dry Creek area appear somewhat contradictory to the reports of residents. There have apparently been three drilled wells constructed, all but one of them being dry holes.

9-12.4 A drilled well of unreported location is described in U. S. Geological Survey Well Schedules (83) as being drilled to a depth of 558 feet. Static water level is reported at 430 feet. A ten foot drawdown at an undisclosed period of pumping at fifteen gallon per minute is reported. No other information is available. Discussions with residents indicate that this well was drilled in 1935 by R. J. Strasser at location 9/12 - 23A1, and is now a dry hole. This location would place the well at the south edge of the basin in an area outcropped by John Day formation, at an elevation of about 1700 feet above sea level. If the location as suggested by residents is correct, the dry well probably penetrated John Day beds for its entire length.

9-12.5 A dry hole, drilled by Mr. Bert Abrams in 1945, on the westerly valley slope at location 9/12 - 10L1, penetrated to a depth of 580 feet. The hole is reported to have penetrated John Day beds for its full length. U. S Geological Survey Well Schedules (83) report "this or another Dry Creek well was drilled to 804 feet in 1935." The dry hole referred to as "another" apparently is the dry hole incompletely described in paragraph 9-11.5.

9-12.6 After drilling the dry hole at 9/12 - 10L1, Mr. Abrams then redrilled about a mile further to the east and on the valley bottom. This well, located at 9/12 - 10R1, penetrated to a depth of 101 feet below the ground surface. The driller reported water ten feet below the ground surface at time of drilling. No performance data are reported. The aquifer is reported as alluvial gravel, the water being perched in alluvial fill at the level of Dry Creek. This well was intended for stock use, a function which it apparently performs satisfactorily.

9-12.7 Occurrence of Ground Water. The geology of the sub-surface formations at Dry Creek cause the development of ground water by wells to be extremely difficult, and in most places impossible. The John Day formation outcrops into the basinal area and lays at great depths. Except in the valley floor where alluvial from younger formations is interbedded in a matrix of ash and tuff, the formations penetrated by wells are anticipated to be so tight and impermeable to not yield usable amounts of water to wells. Wells in the valley floor that draw upon perched waters from the alluvium will generally be weak and not very dependable.

9-12.8 The geology and topography of Dry Creek favor ground water development from springs located on the north side of the basin. Several springs emerge at the lower contact of the massive Clarno uplift that projects into the Dry Creek area from the north. Further to the east the South Block, a massive outcrop of Columbia River basalt yields springs at its lower contact with the John Day beds. Wells drilled in the vicinity of the springs at the edges of the basinal area would probably yield water that would eventually find its way to the existing springs. Such wells probably would have but little, if any, increased capacity over the springs which now exist.

9-12.9 Topographic conditions on the south side of Dry Creek are not so favorable for the occurrence of springs. The Dalles promontory which forms the southwest boundary of the basin is so narrow that it is apparently unable to become sufficiently charged with ground water.

9-12.10 Conclusions. From a standpoint of topography the Dry Creek basin lies favorable for development of ground water by wells. However, the impermeable tuffs and ash of the John Day lie are extensive and are found at great depths. Except in the valley floor where alluvium from younger formations lies interbedded with the ash, wells penetrate into materials so tight that their success is doubtful. All attempts to obtain water in this area from the John Day beds have been failures. Only one drilled well has produced water, it yielding perched water from alluvial fill on the valley floor.

9-12.11 Ground water development in the Dry Creek basin appears to be possible only in the perched waters found in valley alluvium, or in development of springs which exist at the edge of the basin. Springs which emerge on the northerly side of the basin at the lower contact of Clarno formations and at the lower contact of Columbia River basalt suggest ground water development by springs. The Clarno and basalt outcrops to the north are sufficiently massive to be charged with water to produce several perennial springs. Springs on the south side of Dry Creek are not so numerous nor as dependable, due to the limited recharge area of the exposed Dalles Columbia River basalt formations.

Section 9-13: Deschutes Valley

9-13.1 Land Forms and Drainage. Although the Deschutes River flows in a deep and generally steeply cut canyon, there are nevertheless alluvial benches adjacent to the river of sufficient size to permit some farming. Ground water requirements here are generally limited to domestic consumption or other farmstead activity. The river is effluent for its entire course adjacent to the reservation.

9-13.2 Stratigraphy. Wells in the Deschutes valley floor are drilled into recent sedimentary alluvium. The permeable alluvial deposits appear so extensive that wells of fifty feet or less appear to be consistently strong producers. The aquifers in existing wells have been found so permeable and unconsolidated to require casings for the entire depth of the well.

9-13.3 Existing Wells. The Heath Well, 8/11 - 20R1, penetrates thirty-four feet of sand, gravel, boulders, and clay. The well, drilled in 1958 by Mr. L. Kowaleski of Madras, is cased full length with six inch pipe. Static level is reported at twenty seven feet below the surface. Three feet of drawdown is reported after two hours pumping at twelve gallons per minute.

9-13.4 A well at the Village Cafe, two miles east of the Agency, is located near the Deschutes River. The well penetrates sedimentary material, is cased for its full length, and is a good producing well. The well was drilled by Bert Abrams of Madras.

9-13.5 A well drilled by Mr. L. Kowaleski in 1956 at the Glen DeShazer property near the reregulating dam below Pelton Dam penetrates forty five feet of gravel. The six inch cased well is reported to yield fifteen gallons per minute after continuous bailing with no observed drawdown.

9-13.6 Occurrence of Ground Water. At locations on the valley floor and adjacent to the Deschutes River, ground water is generally found in a permeable alluvial aquifer at approximating the level of the river. The sub-surface formations are usually sufficiently unconsolidated to require casing for the entire length of the well. Although the Deschutes River is effluent, a heavy demand on a well will result in a cone of depression that causes withdrawals of water from the river to the well site. Although pollution has apparently not been a problem to these wells, the proximity of the wells to the river and their generally shallow depth in a permeable material are both inviting to the dangers of pollution.

9-13.7 Conclusions. Drilled wells of generally shallow depth can be successfully anticipated when drilled into the alluvial deposits commonly found near the Deschutes River. The duty of ground water at these locations is generally associated with domestic consumption. Capacity of these appears to be invariably more than sufficient for such purposes.

Section 9-14: Metolius Bench, Dry Hollow, and Tenino Bench

9-14.1 Land Forms and Drainage. The bench areas are on all sides, excepting the west side, surrounded by deeply eroded stream patterns. Topographically, both Metolius Bench and Tenino Bench are situated similarly to the area known as the Island. See paragraph 9-9.2. With the exception of a narrow open access to the west, both benches are surrounded by canyons having depths from 800 to 1100 feet. Being in a region of low annual precipitation, ground water recharge is light. As a result, the water-table on the plateaus is everywhere deeply depressed.

9-14.2 Drainage patterns in this part of the reservation are characterized by deeply cut secondary erosions tributary to the main drainage of Seekseequa Creek, Metolius River and Deschutes River. The deeply eroded drainage of Seekseequa Creek extends in a wide belt, being as much as four miles, in width, between Tenino Bench and Metolius Bench. The terrain of the benches slopes towards the east at a gradient between fifty and two hundred feet per mile. Dry Hollow forms an eroded basin to the east of Tenino Bench, lying at an elevation three to four hundred feet below the surrounding bench. Dry Hollow lies at a higher elevation than its name may indicate. While the valley floor of Dry Creek is at an average elevation of but 200 feet above the Deschutes River, Dry Hollow has an average elevation of 2300 feet above sea level, being 800 feet above the Deschutes River.

9-14.3 Stratigraphy. The bench lands in the southeast are generally characterized by a thick mantle of Dalles formation capping John Day beds. The elevation of the upper contact of the John Day formation is not indicated in available well logs, but is probably near 2100 feet above sea level. All logs for wells in the area report penetrating the ash of the John Day. It appears unlikely that any existing wells penetrate into the John Day further than the upper poorly defined contact, where the overlying Dalles sediments grade into the John Day. Such deposits are expected to be quite tight and relatively impermeable.

9-14.4 Adjacent to portions of the Metolius and Deschutes River the relatively porous and permeable intracanyon basalt remains as discontinuous ledges. The basalt is more or less continuous vertically to the level of the existing stream bed. Wells drilled through the basalt would be expected to yield good wells. No wells are at present located in such a close position to the rivers, nor is their occurrence so close to the river in this area likely.

9-14.5 Test Holes. One test hole, drilled by the Portland General Electric Co., (49) has been drilled on the Metolius Bench. The hole is located about one mile west of the Round Butte dam site. A log of the hole appears in Appendix IX-H. The 642 foot hole penetrated materials consisting primarily of basalts and sandstones. The apparent piezometric elevation after completion of the hole was at an elevation of 1787 feet above sea level, or at a hole depth of 430 feet. This is approximately two hundred feet above the elevation of the stream bed of the Deschutes River.

9-14.6 Below an elevation of about 1850 feet above sea level the formations appear to be dense and quite impermeable. The general impermeability of the deeper materials are also indicated by the steep slope of the apparent water-table near the Deschutes River. The frequent flow contacts encountered at various elevations of the test hole are typical of perched water conditions elsewhere on the reservation. This test hole indicates that a well adequate for stock or household use, one to two gallons per minute, is probable from a well 450 to 500 feet deep.

9-14.7 Existing wells. Records show five wells to have been drilled in the southeastern portion of the reservation. The descriptions of two of these are contradictory, and are apparently meant to be the same well.

9-14.8 The Dry Hollow well, 10/12 - 15E1, was drilled by R. J. Strasser. The location is at an elevation of 2150 feet above sea level. The date of drilling is not reported, but is probably 1935. The well is cased with six inch pipe to an undisclosed depth and drilled to a reported depth of 288 feet below the ground surface. No data of subsurface formations, or well performance are known. The well apparently has a discharge sufficient for stock and domestic use.

9-14.9 A well at location 10/12 - 31K1 at an elevation of 2440 feet above sea level, reported in U. S. Geological Survey Well Schedule (83) as the Annie Smith well, appears to be the same well that is described in the same records and listed on U. S. Bureau of Indian Affairs maps as the Johnson #2 well. The well, reported to have been drilled by Mr. Bert Abrams in 1935, was apparently constructed by R. J. Strasser in that year. The well apparently has either a six or eight inch casing and is either 333 or 402 feet in depth. Records indicate that the well passes through the Dalles formation into the upper John Day beds. Performance is not definitely known, one source indicates fifteen gallon per minute with a ten foot drawdown after an undisclosed period of pumping. Such a large capacity for a well in this area is questioned. Residents report the well to be a good, strong stock well. No additional information is available.

9-14.10 A well, known as the Wewa well, at location 10/12 - 34E1 was originally drilled by R. J. Strasser in 1935 to a depth of about 600 feet. The well is located at an elevation of 2040 feet above sea level. This six inch partially cased well silted in about 1946. In 1948 Mr. Bert Abrams redrilled the well to a depth of 616 feet. At this time static water was reported to be 345 feet below the ground, substantially the same level originally reported in 1935. The well now contains 390 feet of six inch casing. At the time of redrilling capacity of the well was reported by Mr. Abrams to be two to three gallons per minute with fifty-five feet drawdown after a short bailing time. The well again silted in during 1959, and is now inoperative. Pipp spring, located about a mile and a half to the southwest, now supplies water to stock.

9-14.11 The aquifer of the Wewa well is reported by well schedules (83) to be John Day. Mr. Abrams, who grouted and redrilled the well in 1948, reports the well to be a good well as the water-table appears to be in sedimentary conglomerate, probably Dalles deposits or Dalles in a matrix of John Day. The repeated silting of this well suggests treatment by well development.

9-14.12 The Estabrook well, 11/12 - 18P1, is a six inch well that is now drilled to a reported depth of 370 feet. It is drilled in vesicular lava rock, tuffs, sandstone and gravel. The well is reported to have been drilled three times. At the present drilling the well is reported to have a static water level 260 feet below the land surface, and to yield twenty gallons per minute with a test bailer. Duration of the test is not known, although it would appear that the well could sustain a flow of twenty gallons per minute for short periods only. The driller reports that at the time of drilling (probably the first drilling) that water stood in the well 152 feet below the land surface. It is likely that the well discharges perched water.

9-14.13 Occurrence of Ground Water. Ground water in the bench areas of the southeast portion of the reservation, or in basinal areas, apparently occurs in the lower reaches of the Dalles formation, or at upper levels of John Day beds. Existing drilling logs are not clear in describing the aquifers of this area, being described as either Dalles or John Day. The plateaus, surrounded by deeply eroded drainage and located in an area of low precipation, are expected to have an aquifer having little depth.

9-14.14 It is not known if water produced by the four wells is true ground water or is from perched sources. In each of the four wells in this part of the reservation, water is drawn from elevations considerably above the nearest effluent rivers. If water produced by these wells is ground water, the water-table must be so steep to indicate a tight and generally impermeable aquifer. If the water is perched water, aquifer capacity is expected to be limited. In any event, the occurrence of water available to wells in this portion of the reservation appears to be limited to capacities less than five gallons per minute and to be found at depths from 300 to 600 feet below the surface of the ground.

9-14.15 Conclusions. Although four wells exist in the area, information from driller's logs or from well performance data appears incomplete and unreliable. Prior to further ground water development, well performance data from these wells should be obtained. Driller's logs for proposed wells should carefully indicate the presence of perched water and type of formations penetrated.

9-14.16 The unsatisfactory performance of the Wewa well indicates the need for fully cased holes and well development where sedimentary deposits are penetrated. Although the Wewa well appears to be the only well on the reservation which suffers from excessive encroachment of fine material, the use of well development would probably be advantageous to all wells receiving water from sedimentary beds.

9-14.17 It appears unlikely that wells having substantially greater discharges than the present wells can be drilled on the bench lands in the southeast. Existing wells appear to penetrate into the upper portions of the John Day beds. Although wells here strike water at elevations of 200 to 600 feet above the Metolius or Deschutes River, wells drilled to deeper depths would probably not have increased yield. Additional depth of hole, penetrating into the tight John Day that underlies the matrix of Dalles and John Day, would yield little, if any, additional water.

9-14.18 The "island" characteristic of the topography of both the bench lands, surrounded by deeply eroded canyons on all but the narrow neck of unbroken terrain to the west, practically eliminates the possibility of striking ground water at sub-surface elevations greater than 2100 feet above sea level. Although the Dalles formation has great thickness on the bench lands, the regional water-table probably lies near the top of tight and impermeable John Day beds. It is concluded that much of the water that is produced by wells in this area is from perched sources. Except where impermeable subsurface barriers lie most favorably, it would appear that the limited rainfall and limited recharge area of the bench would generally prevent wells yielding sustained discharges exceeding five gallons per minute.

Section 9-15: Ground Water in Other Areas.

9-15.1 Coyote Creek, Beaver Creek and Log Springs. No drilled wells exist in the area north and west of Simnasho. The area has a geology characterized by Clarno, John Day and Dalles formation. Beaver Creek has its watershed primarily to the west in terrain outcropped by Dalles deposits. The watershed of Coyote Creek lies mainly to the east in terrain exposing Clarno and John Day beds. The topography between the two creeks consists of a Dalles plain in the south, and a Dalles upland in the north. Surface drainage between the two creeks is approximately equally divided.

9-15.2 Numerous springs are evident in this area. The development of these effluent seepage areas offer the most readily available source of ground water. Where springs are not sufficiently proximate to desired point of water delivery, wells appear to be possible. Wells penetrating Dalles deposits would probably offer the strongest discharge. Where the Clarno formation is the principal aquifer, yields are anticipated to be extremely variable and the depths of wells uncertain. The numerous springs in the area indicate that wells drawing upon either perched water or free ground water would be successful at depths not generally exceeding 200 feet. Such wells would not be expected to have discharges significantly different than the springs which emerge in the area.

9-15.3 Mutton Mountains. The Mutton Mountains are an ancient Clarno uplift, although an extensive area of John Day appears exposed northeast of Simnasho. This portion of the reservation is severely eroded. Numerous undeveloped springs emerge at the lower elevations of the topography. The improvement of these undeveloped springs appears to offer the most practical source of ground water for both domestic and range use. It is doubtful that wells in this area would offer discharges exceeding that from a properly developed spring.

9-15.4 One drilled well exists in the geographic area of the Mutton Mountains, the Charley well, 8/13 - 9K1. The well was drilled to a depth of 125 feet in 1959 by Lawrence Kowaloski of Madras. The well is reported to penetrate a red clay for nearly its entire depth. The discharge by driller's bailer is three gallons per minute, which approximates the flow from the numerous springs along the lower slopes of the Mutton Mountains.

9-15.5 North and South Block (Webster Flat). The areas known geologically as North Block and South Block (Webster Flat) are two Columbia River basalt plateaus that lie to the north and to the south of the Warm Springs River near its confluence with the Deschutes River. The plateaus lie at an elevation approximately 2200 feet above sea level. Hill-side springs exist at elevations considerably below the elevation of the plateaus, leaving rather extensive areas on the plateaus without stock water. Wells drilled at the top of the plateaus would have an advantage for ground water development solely for considerations of point of delivery. The anticipated depth of a well to provide the minimum requirements of stock water is not known. The location of the existing springs indicates well depths exceeding 400 or 500 feet would be required to tap the perched water that appears on the hillsides as springs. Wells here would likely penetrate Columbia River basalt for their entire depth, a formation that is difficult to drill with the type of drilling equipment used locally.

9-15.6 Valley Alluvium. Wells drilled into the recent alluvium on the valley floor of perennial streams of the reservation are expected to be good wells. Sedimentary deposits along such streams as Warm Springs River, Shitike Creek, Tenino Creek, Beaver Creek, Badger Creek, Seekseequa Creek and other streams on the reservation appear sufficiently permeable to provide a strong aquifer to relatively shallow drilled wells. Wells at such locations are expected to be used for domestic water. Because such wells will be shallow, they are particularly suspect to the dangers of pollution. Ground water at valley floors containing perennial surface water is usually available from nearby springs or diffuse effluent seepage. The development of these springs will in many cases be more satisfactory than the water from the shallow wells constructed on the valley floor.

9-15.7 The Freeland well, 8/13 - 20G1, drilled into 39 feet of the valley floor near the Warm Springs River, is an interesting though probably not typical example of a recent alluvium well. Static water level of the six inch cased well is reported at seven feet below the ground surface. This well discharges at 32 gallons per minute with one foot of drawdown. The well apparently draws partially from thermal sources, as the well produces water at a temperature of 105° F.

Section 9-16: Summary.

9-16.1 Ground Water Investigations on Reservation. One investigation directed toward the utilization of ground water on the reservation is known to exist. This is a study which was made by the Portland Branch of the U. S. Geological Survey in 1955 and 1956, and conducted for the purpose of finding a source of domestic water for the Schoolie Flat area. Water resources studies of areas adjacent to the reservation have treated the ground water problems in those areas. During the summer of 1940 the Kah-Ne-Tah Spring and adjacent thermal springs were investigated by Joseph E. Upson by authority of the U. S. Geological Survey.

9-16.2 History of Well Construction. An extensive well construction program was undertaken by the Bureau of Indian Affairs which resulted in eight drilled wells being completed on the plateau regions of the reservation in 1935. The wells were constructed by a contractor, R. J. Strasser of Portland. Windmill, storage tank and stock watering tank were installed by contract at each well. All the wells produced water but one, a dry hole in the Dry Creek basin. Of the remaining seven wells, four are in operation today.

9-16.3 Since 1935, seven drilled wells are known to have been constructed. All but one, a deep dry hole in the vicinity of the dry hole of 1935 at Dry Creek, have been successful ventures. Three of these wells are located on plateau lands, the remaining being located in valley alluvium. These wells have been constructed by two drillers from Madras, Bert Abrams and L. Kowaleski.

9-16.4 Dug wells on the reservation are usually satisfactory for considerations of capacity as they are located in a permeable soil mantle in locations proximate to springs or other surface drainage. However, most of these wells have become polluted to such a degree as to be declared unsafe by the Bureau Indian Health.

9-16.5 Well Logs and Performance Records. Incomplete drilling logs are available for wells constructed on the reservation. In but few instances is drilling information available in detail sufficient for a geologic study of water-bearing formations. Only one drilled well on the reservation is known to have had a sustained performance test after removal of drilling equipment. Drilling and performance information appears to be available in greater detail for those wells constructed in recent years.

9-16.6 Drilling Equipment and Development. All drilled wells on the reservation have been constructed with cable-tool or percussion equipment, a type of drilling equipment which permits good observation of subsurface hydrology and geology. Many of the wells penetrate formations so consolidated to permit uncased holes, except for short lengths of casing near the surface required for a sanitary seal. Grouting of the uncased holes helps to prevent loss of perched water and stabilizes the material at the hole. Well development to increase yield or to prevent encroachment of fines has not been utilized on any of the wells on the reservation. At most of the existing wells, the aquifers are found in formations too consolidated to respond to development. However, where wells draw upon water from the more unconsolidated sedimentary materials of John Day and Dalles mixture, it appears that development would be helpful. Drilling costs in this area are reported to be approximately $6.00 per foot for a well cased 20 percent of its depth with six inch pipe.

9-16.7 Well Operation and Maintenance. The lack of electric utility service at most areas of the reservation requires the use of wind driven pumps. A systematic program of preventive maintenance to both windmill and pump would undoubtedly remove much of the dissatisfaction expressed by users towards the wind driven pumps.

9-16.8 Hydrology of Wells on Reservation. There is no evidence of non-thermal confined water on the reservation. Drillers having experience on the reservation are of the opinion that wells yield free ground water, and often produce water from perched sources. Wells in areas of the reservation giving rise to perched water springs appear to have no great advantage over the springs themselves. A sole advantage might be a more convenient point of delivery. Wells that are known to obtain water from the deeper formations apparently draw from aquifers that are generally tight and incapable of yielding but minimum discharges. Formations often vary widely within a small area. This causes predictions of ground water based on topographic outcroppings or incomplete drilling information from widely scattered wells exceedingly uncertain. The position of the water-table on the reservation is not known. Numerous zones of perched water are thought to exist. The upper contact of the John Day ash probably determines the minimum elevation of the effective water-table.

9-16.9 Duty and Quality. Except for wells located in valley alluvium and adjacent to perennial streams, discharge is expected to be so small that the duty of water is limited to domestic consumption, stock and possibly irrigation for small garden plots. Wells are expected to yield soft but palatable water. Because of surface alkali, the shallower wells usually yield the harder water. Pollution of ground water intended for human consumption is the most urgent existing ground water problem on the reservation today. The importance of the situation is realized by the Bureau of Indian Health, who have drafted preliminary plans for its correction.

9-16.10 Schoolie Flat. Deep wells drilled on Schoolie Flat appear to have aquifers of Clarno and Dalles beds. Four drilled wells exist on the reservation, having depths ranging from 139 to 565 feet. There appears to be little correlation of well depth to topography. Well logs indicate the strongest well is capable of five or ten gallons per minute. Topography and geology of Schoolie Flat are generally favorable for development of ground water by wells having depths less than 500 feet and discharges sufficient for domestic and stock use. Wells on Schoolie Flat are extremely variable in type of aquifer. Locations of ancient alluvium from the Clarno hills appear to be interbedded in impermeable formations that support perched water. Ground water from wells appears to offer a more satisfactory source of domestic water than that obtained from an extensive distribution system supplied by limited spring discharge issuing at the extreme east edge of the Flat.

9-16.11 Sidwalder Flat. The Dalles formation appears to dominate wells drilled at Sidwalder Flat. Drainage forming the boundary of the plateau is not as deeply eroded as that found near many other bench lands. The one drilled well of 407 feet in depth is reported to probably penetrate a lava ash. The entire bench is open to ground water recharge from Sidwalder Butte. Wells here would appear not likely to require drilling below the 2100 foot elevation contour, the probable upper contact of the John Day beds, and would probably have yields equal to or surpassing the wells on Schoolie Flat. The immediate solution for domestic water appears to be the utilization of treated surface waters which flow into the shallow wells from the irrigation unit. The lack of central electric utility service in this area at this time prohibits the use of most commercial automatic hypochlorinators.

9-16.12 The Island. The deeply eroded drainage that nearly entirely surrounds the Island prohibits the occurrence of ground water from wells generally less than 500 feet in depth. Wells at such depth are likely to penetrate tight aquifers, and be capable of but small discharge. It is unlikely that additional wells on the Island will have yields significantly different from that now obtained at the one existing well.

9-16.13 Miller Flat. Ground water on Miller Flat probably occurs at conditions similar to that found on Sidwalder Flat. Both bench areas have similar topographic characteristics. Geology of both areas appears substantially the same. Well logs of the single drilled well at each area indicate that the aquifer of the Miller Flat well may be more permeable than that found at the Sidwalder well. In the absence of current irrigation development on Miller Flat, deep wells appear to offer the only practical source of domestic water. The success of the one existing well indicates ground water to be available in the interior or westerly portions of the bench at depths not exceeding 400 feet, and in amounts satisfactory for stock and household use.

9-16.14 Dry Creek. Dry Creek basin lies at an elevation at or below 1700 feet above sea level. John Day ash dominates the geology.

With the exception of a 100 foot well drilled into valley floor alluvium which receives perched water, all attempts to drill deep wells in the Dry Creek basin have been failures. Ground water development from the springs that issue at the edge of the basin appear to offer a practical source of ground water where desired point of delivery is within reasonable distances.

9-16.15 Deschutes Valley. Wells drilled into the valley floor appear to penetrate an alluvial aquifer that assures a strong flow into wells. All drilled wells are reported having depths of fifty feet or less and to have sustained discharges exceeding twelve gallons per minute. These wells penetrate permeable unconsolidated formations requiring casing for their entire depth.

9-16.16 Metolius Bench, Dry Hollow, and Tenino Bench. The bench areas topographically resemble the Island. Both appear as high plateaus nearly entirely surrounded by deeply eroded drainage. Three wells in the southeastern portion of the reservation apparently receive ground water from the lower portions of the Dalles sediments near the contact with the John Day ash. Little information is available regarding well performance of wells in this area. It appears unlikely that wells would offer discharges greater than five or six gallons per minute. The existing wells average four to five hundred feet in depth. The Wewa well, drilled to a depth of six hundred feet, has repeatedly silted in. In such situations, well development would appear to increase discharge and minimize the dangers of silt encroachment. Wells located on the bench to the south of the Wewa well would probably require depths exceeding six or seven hundred feet unless extensive zones of perched water were encountered. Wells penetrating the Intracanyon basalt at the edge of Metolius and Deschutes Rivers would require depths reaching to elevations of the river surface.

Section 9-17: Recommendations

9-17.1 Pollution. Correction of conditions contributing to pollution of wells on the reservation is vital to the health of the residents. The immediate correction of existing sanitation deficiencies of well construction is recommended. The dug wells appear generally to lack construction and maintenance necessary to prevent pollution from surface drainage or contamination of the ground at the well or proximate refuse areas. It is suggested that all existing wells and proposed wells be constructed and maintained in accordance with recognized sanitation practices. The educational problems of obtaining effective support by the residents of such a program should be the responsibility of the Bureau of Indian Health.

9-17.2 The drilled wells of the reservation are all installed with casing intended to act as a sanitary seal at the ground surface. However, the present practice of installing stock watering tanks beside the well invites contamination of the ground adjacent to the well and subsequent pollution through a faulty seal. Where such wells are also used for domestic purposes, the purity of water is suspect. Stock watering tanks, removed from the well by a safe distance of one to two hundred feet, can be easily served by a buried pipe from a storage tank at the well. Such an installation does not require access of stock to the well, and is preferred from considerations of pollution problems.

9-17.3 Drilling Logs. Detailed and accurate drilling logs serve as a valuable source of information to the geology and hydrology of proposed wells. Drilling logs for all future wells should be completed by the driller at the time of drilling, show in general the detailed information described in paragraph 4-3.2, and be available in Agency files.

9-17.4 Performance Tests. Very little is now known of the capacity and other discharge characteristics of existing wells on the reservation. Prior to any new well construction, performance tests are suggested on the existing wells. Performance tests of all wells should be periodically made to correctly determine their hydraulic characteristics. Such information is useful for better utilization of ground water at existing wells, and for effective planning of proposed ground water development. The performance records for all wells on the reservation should be available in Agency files.

9-17.5 Maintenance. A systematic program of preventive maintenance of both well and pumping unit is ssuggested. Periodic inspection and upkeep would improve dependability of pumping equipment, and minimize dangers of pollution.

9-17.6 Well Development. The use of well development practices is suggested where aquifers appear to be tight but unconsolidated or unstable. These formations on the reservation are probably restricted to the finer Dalles sediments, or at the lower contact of the Dalles where it grades into the John Day ash.

9-17.7 Ground Water from Springs. Wells drilled in areas of effluent seepage probably will not produce discharges generally exceeding that received from a properly designed spring development. The advantage of wells in such a condition is the more convenient point of delivery, an advantage which can often be economically achieved by a distribution line from the spring. Spring developments requiring extensive distribution systems should be based on more accurate spring discharge data and water demand information than is now available.

9-17.8 At Schoolie Flat several springs issue at the toe of the Mutton Mountains. The discharge or seasonal fluctuations of these streams are only approximately known. Ground water from developed springs to serve Schoolie Flat would require an extensive distribution system with intermediate storage. The construction based on such meager hydraulic data or population trends of the area is not justified. The information now available, however, indicates that a series of wells on Schoolie Flat offers a more practical solution.

9-17.9 Well Drilling Program. It is suggested that well construction on the reservation be closely coordinated with spring development and surface water storage. Proposed well construction should not only be based on all available history of existing wells, but also include the feasibility of spring development and use of surface water storage. The use of surface waters and their treatment for domestic use is discussed in Chapter 10. Money spent for construction of the Wewa well could have been more effective if directed toward the development and distribution facilities of Pipp spring. Surface storage on the non-perennial water-ways has not been generally successful on the reservation. However, increased attention to watershed run-off, and losses caused by evaporation and seepage at the reservoir are expected to improve performance of surface storage structures.

9-17.10 Unit Costs. Unit costs are expected to be the most favorable when wells are constructed by contract. The specialized equipment and operating personnel required of well construction renders a force account operation not advisable. A contract for the construction of several wells is more attractive to a driller than is the opportunity to drill a single well, and can generally be expected to result in lower unit bed costs. It will be to the advantage of the residents that such contracts also be explicit in the requirements of drilling logs or other performance data.

CHAPTER X

DOMESTIC AND STOCK USE OF SURFACE WATERS FROM PERENNIAL AND NON-PERENNIAL STREAMS OF THE RESERVATION

Satisfactory use on the reservation of non-perennial surface waters impounded in small reservoirs or charkos has been limited to stock water. These structures, often constructed of permeable fill and flooding a permeable terrain, appear to suffer large seepage losses, and sometimes fail to retain adequate storage through the dry summer months. Biological treatment of water from ponds, irrigation ditches, or shallow wells is recommended when these sources are used for domestic purposes.

Section 10-1: Records and Source of Data.

10-1.1 History of Construction. The first extensive program for construction of surface water storage structures apparently was undertaken by the Civilian Conservation Corps in cooperation with Bureau of Indian Affairs and Soil Conservation during the 1930's. With the exception of one dam, all were of earth fill construction. Dams constructed by the CCC were generally in the northeast portion of the reservation, being in the vicinity of Simnasho or on Schoolie Flat. Six dams are reported (73,p.46) to have been completed, a seventh dam abandoned before completion. The soil mantle in this area and the formations directly underlying are generally sufficiently impermeable to be well suited for earthen dam construction. All the dams known to be built by the CCC program stand today, and reportedly hold water throughout the year.

10-1.2 A record of charko construction on the reservation is not known to exist. Charkos have been constructed in the eastern portion of the reservation where stock water from springs, wells, or perennial streams is inadequate. The storage capacity of charkos seldom exceeds one-half acre-foot. Many of the charkos exist on Miller Flat, and although numerous, are reported to be dry after the early summer months.

10-1.3 Small dams have been constructed by personnel and equipment of the Bureau of Indian Affairs. These sites have been generally at the easterly portion of the reservation north of Shitike Creek. Very little information regarding their construction is available. Records of the Land Operations Office do not indicate compaction tests, permeability specifications, or other details of construction. Unit cost of excavation is reported as $0.25 per cubic yard.

10-1.4 Inventory. An inventory of surface water storage facilities on the reservation is shown in Appendix X-A, and plotted on map Appendix VIII-B. The compilation was made as a result of field observations and interviews with residents and personnel of the Land Operations Office.

Section 10-2: Duty and Quality.

10-2.1 Duty. The small dams and charkos on the reservation have been constructed primarily as a source of stock water. However, a small dam if capable of holding water in its reservoir throughout the summer months can satisfactorily serve as a source of domestic water, provided approved treatment as suggested in section 10-6 is provided. Limited reservoir capacity and recharge rate in an area of limited annual precipitation generally is insufficient for irrigation requirements. One dam, the Happy Valley dam having a reservoir capacity of approximately 385 acre-feet, although by far the largest dam on a non-perennial stream, has proven to have inadequate capacity for the irrigation unit at Simnasho. With the exception of the Happy Valley dam, no dam or charko on the reservation impounds a greater amount of water than approximately 40 acre-feet.

10-2.2 Dams constructed in the Simnasho and Schoolie Flat area have usually proven to be sufficiently tight at both dam and reservoir, and have adequate annual recharge from the watershed to hold water throughout the summer months. Further to the south, on Miller Flat, the existing charkos and dams often are unable to retain stock water throughout the year.

10-2.3 Quality. Quality of impounded water has not been a problem where its use has been for stock water. However, where these and other surface waters have been used for domestic purposes, the water has usually been found to be unsafe when untreated. Such waters may be from unprotected springs subject to surface contamination, water direct from irrigation ditches, small dams, or water from very shallow wells that draw upon surface waters. The dangers of use of polluted water has been described elsewhere in this report.

10-2.4 Although biological treatment of water is not suggested as an alternative to reasonable precautions against contamination, where water supplies are economically limited to sources of contaminated surface water, the use of approved water treatment procedures may present the only solution to adequate sources of domestic water. The use of approved water purification processes applicable to rural water supplies is suggested at areas of the reservation, such as Sidwalder Flat, where abundant sources of surface water from the irrigation unit are found, and where ground water is at the present time undeveloped.

10-2.5 Surface waters dissolve very little mineral from lava terrains, hence from a mineral standpoint the water of the small dams is generally expected to be excellent. Because of surface alkali, some water may be slightly alkaline.

Section 10-3: Geographic Factors Affecting Design.

10-3.1 Geographic Factors. Geographic factors which appear to have the greatest effect upon the success or failure of the small dams on the reservation are topography, permeability, nearness of the water-table to the ground surface, and climatology. The effect of each factor is dependent upon the other. Each can vary greatly within different but proximate sites. At locations on the reservation where small dams are feasible, both the climatology and position of the water-table remain relatively constant from site to site. While the position of the water-table with respect to the ground surface is a factor of runoff intensity and deep percolation at a dam site, the water-table at most feasible sites on the reservation is so far below the ground surface that its effect probably is everywhere nearly constant.

10-3.2 Topography. A steeply inclined terrain at the watershed has a favorable effect upon quantity of runoff reaching the reservoir. The time of concentration at a reservoir having a steep watershed terrain is small, allowing for minimum percolation into the permeable soil mantle above the reservoir. On the other hand, a reservoir draining a nearly flat and unbroken watershed may receive little, if any, runoff regardless of the size of drainage area involved. The need for small dams and charkos on the reservation is in areas devoid of other natural sources of stock water. These natural sources, being perennial streams, or springs, are usually found in rough and eroded terrain. As a rule, the need for development of surface storage of water from non-perennial watersheds is in areas of the reservation having relatively flat or gently rolling terrain, such as Schoolie Flat or Miller Flat.

10-3.3 The relatively large watersheds on Miller Flat that serve the existing dams located below generally poorly defined waterways show evidence of small amounts of runoff. The lack of an adequate reservoir recharge is due in part to the gently rolling terrain in this area. The Red Lake dam constructed in the uneven Clarno topography north of Simnasho has a watershed limited in size to approximately 450 acres, but is sufficiently rolling to annually fill the 12 acre-foot reservoir.

10-3.4 Permeability. Permeability of the soil has a direct effect upon the success of a small dam due to seepage at the watershed, at the reservoir, and at the dam. Discharge of water through a soil is directly proportional to the cross-sectional area of soil conduit, the hydraulic gradient of flow, and the permeability of the soil. The hydraulic permeability of a porous material is its characteristic property of transmitting water through its interstices. The degree of this property is called the coefficient of permeability. Several methods are used to determine the coefficient of permeability. See paragraph 10-4.9.

10-3.5 The success or failure of the small dams and charkos appears to be more greatly influenced by the degree of permeability of the soil than any other single geographic feature. A watershed, reservoir floor, or impounding structure formed by a permeable material is accompanied by heavy seepage. Considerable loss can occur at a permeable watershed, particularly if the watershed is rather flat. Deep percolation and seepage can occur through a reservoir floor and impounding structure when formed of impermeable materials. With the exception of those parts of the reservation exposing Clarno or John Day formations, the topography is generally permeable. The Dalles formation which is exposed throughout a great portion of the reservation is a basaltic deposit that is usually extremely permeable at its upper levels.

10-3.6 Stearns (35, p.701) reports that basalt in any part of a reservoir site should be regarded with suspicion. Reservoirs in basalt generally fail because the water table is far below the floor of the reservoir, with only permeable rock intervening. This situation generally prevails at sites on the reservation where small dams are desirable. While there is no practical method of decreasing the permeability of the watershed, nor would it be desirable from other considerations, there are methods available to the engineer to improve permeability characteristics of the dam. The reservoirs of the small dams and charkos are generally of a limited size where it appears treatment of the reservoir floor to prevent deep percolation is feasible. Suggested methods for treatment are discussed in Section 10-4.

10-3.7 Water-Table. In general, wherever small dams or charkos are desired on the reservation as a source of stock water, that location will be at a site having a depressed water-table. This has the effect on the hydraulics of small dam construction of increasing losses at both the watershed and at the reservoir.

10-3.8 Climatology. The need for small dams on the reservation exists generally only at the easterly portion of the reservation, an area of low annual precipitation. Although the amount and distribution of precipitation varies somewhat, the plateau regions where dams are required have a more or less consistent annual precipitation of 10 to 13 inches per year. During the year, approximately 30 percent of the precipitation occurs during the six summer months. See Section 5-3. Because of the unfavorable distribution of a meager annual precipitation, it is imperative to the success of small dams that seepage losses at the dam and reservoir be kept to a minimum.

10-3.9 An important difference exists between a reservoir built to retain water for a few weeks and one built to store water for the greater part of a year. The time and duration of runoff, and the demand upon the reservoir are influential factors. Rains on the reservation after April or May are seldom of duration or intensity to bring runoff to the reservoir. For the reservoir to hold water during the entire year, consumptive demand and natural losses incurred during the interval of approximately May through October must not exceed rechargeable reservoir capacity.

10-3.10 Three factors prevail on the reservation that contribute to high reservoir losses due to evaporation. These are the difference between the pressure of saturated vapor at the temperature of the water and the vapor pressure of the air, the prevailing winds that blow across the reservation, and the general small size of the reservoir. Evaporation is affected by the temperature of both the air and the water. The rate of vapor emission is dependent upon the water temperature, the rate of vapor removal is affected by the temperature of the air. The vapor holding capacity of the air varies with its temperature, and the difference in vapor pressure betweeen the water and the air is directly affected by the temperature of the air. Wind could be considered a secondary cause of evaporation, for its effect is to remove from the vicinity of the small pond the cooled moisture laden air and replace it with warm dry air that readily absorbs more moisture from the pond surface. The small size of the reservoirs assists the moisture interchange described above, contributing to warmer water temperatures which have the secondary effect of accelerating vapor emission from the water surface.

10-3.11 Watershed Runoff and Reservoir Loss. There appears to have been little, if any, investigation directed toward watershed runoff, permeability of reservoir, permeability of the dam, or the anticipated losses through evaporation at the small dams constructed on the reservation. Discussions with personnel of the Land Operations Office indicate a lack of data regarding runoff, permeability tests of reservoir and dam, and probable evaporation losses. The conclusion is that the small dams of the reservation have been generally designed and constructed without regard to the basic engineering precepts that give reasonable assurance of their success.

Section 10-4: Minimizing Evaporation and Seepage.

10-4.1 Loss at the Watershed. The only effective way to overcome large watershed percolation is by the proper selection of the reservoir site. Runoff from the watershed is due to the combined effect of topography, rainfall intensity and duration, water-table location, and permeability. Practically, these factors of the watershed are beyond the control of design. The dam site must be selected where the existing conditions provide sufficient runoff to the reservoir.

10-4.2 Loss at the Reservoir and Dam. Two principal losses occurring at the reservoir and the dam are evaporation and seepage. At the small dams on the reservation, losses due to seepage through the dam and through the reservoir floor appear to be predominant. No known measurements of either type of loss exist at any of the small dams om the reservation.

10-4.3 Measurement or Estimation of Evaporation. Harding (35, p. 56) suggests five methods of determining evaporation, (1) theoretical analyses, (2) computation from formulas based on atmospheric elements, (3) computation from formulas based on energy transfer, (4) observations with various types of pans or atmometers, and (5) direct records from large water areas. However, the difficulties in deriving the relations between evaporation and the climatic or energy items necessary in the formulas have led to the general use of direct observations from controlled water surfaces. The difficulty of making direct measurements of evaporation from large water surfaces has led to the use of many types of small water areas in tanks or pans and other special surfaces such as those used in atmometers. Atmometers have their greatest use for estimating transpiration. All these instruments attempt to correlate the various climatic factors affecting evaporation with the measurable loss of the controlled surface.

10-4.4 Pans have been found to have larger rates of evaporation than adjacent large water areas. The coefficient which is necessary to apply to the pan results vary with the size of the pan and its position with respect to the reservoir. Coefficients approach unity for large pans. The standard land pan of the United States Weather Bureau is four feet in diameter, ten inches deep, and water is maintained within two to three inches of the top. This pan has been used in the United States more extensively than any other. Coefficients have been reported by Rohwer (51) having a mean of 0.70 and a range of 0.91 to 0.57 in different months. Harding (35, p. 75) suggests, on the basis of present available records, a general coefficient of 0.70 for reducing observed evaporation from this type pan. Floating pans have been used in an attempt to establish conditions similar to those of the surrounding water. Such pans are subject to splashing during winds even when surrounded by a raft. Floating pans are not as generally used, Harding (35, p. 76) advising when they are used to install a land pan also. The United States Geological Survey floating pan is 18 inches deep, and three feet square. Diagonal baffles reduce wave action. Coefficients ranging from 0.70 to 0.91 are reported by Rohwer (51), with 0.80 recommended as a mean value.

10-4.5 The determination of evaporation for the small reservoirs of the reservation is suggested. Measured evaporation from either land pans or floating pans appear to offer the best method.

10-4.6 Evaporation from the small reservoirs on the Warm Springs Reservation is anticipated to approximate evaporation measurements recorded at the Cold Springs Reservoir, Umatilla Project, Oregon. Harding (35, p. 61) presents data of the relation of mean monthly air temperature and evaporation. The climate of Umatilla during the months of May through October is arid, and quite similar to that found at Warm Springs. During this period the average monthly evaporation from floating pans was observed to be 7.5 inches. Using a coefficient of 0.80, the computed reservoir evaporation during these months is three feet. Three feet of evaporation loss from the generally shallow reservoirs of the small dams or charkos constitutes a large portion of their total reservoir capacity.

10-4.7 Minimizing Evaporation. There is not much that can be done to reduce evaporation at the small reservoirs. Of necessity, the reservoir size is small, and often quite shallow. Both of these physical characteristics contribute to warm water temperatures, which in turn hasten evaporation through the process described in paragraph 10-3.10. In deep bodies of water, temperature changes extend to considerable depths. The warming of the deeper depths of water in the spring and early summer utilizes some of the heat supply that would otherwise be available for evaporation. During the cooler months of the fall or early winter the stored heat of the water makes available a heat supply in excess of that received then from the atmosphere. As a result, the evaporation from the deep waters is reduced during the spring and early summer, and increased during late fall or early winter. Rainfall existing at the reservation cause such an evaporation pattern to be desirable.

10-4.8 In so far as practical by the topography of the reservoir site, total evaporation during the dry summer months will be minimized by reducing the surface area of the reservoir and gaining capacity by greater reservoir depth. Such corrective action is practically limited to smaller reservoirs of comparatively shallow depth.

10-4.9 Measurement or Estimation of Seepage. Three factors contribute to seepage at the reservoir and dam, (1) hydraulic gradient, (2) cross-sectional area of the soil conduit, and (3) coefficient of permeability. The first two are a function of the geometry of the dam and reservoir. The last is a function of soil texture and structure. Rate of seepage is the product of the three factors. The permeability coefficient is the only non-geometrical term needed to estimate seepage loss through either the dam or reservoir.

10-4.10 The different methods of determining coefficient of permeability are grouped as (1) field discharge methods, (2) field velocity methods, (3) direct laboratory methods, and (4) indirect laboratory methods. The permeability of a given sample can be accurately determined in the laboratory by direct methods. For such tests undisturbed samples are suggested, but not necessary. Permeability is computed from mechanical composition and porosity in indirect laboratory methods.

10-4.11 Various types of testing procedures and equipment have been devised to measure the permeability of a soil sample. A simple procedure requiring a minimum of equipment is described in a Manual for Inspectors for Earth Dams by the Engineering and Construction Departments of Tennessee Valley Authority (28, pp. 64-66, fig. 20). The necessary equipment is: a portable permeability-consolidation cylinder (five inch diameter) with weights, porous loading stone, and fulcrum, dial gauges, filter paper, gaskets, shellac, and burette. Three observed quantities, temperature of the water, time duration of test, and burette reading are used to directly obtain the permeability coefficient from a nomograph.

10-4.12 The value of permeability tests of the dam materials and the reservoir floor is for the estimation of seepage losses prior to construction. Where the small dams and charkos are constructed on the permeable Dalles materials, a reasonably accurate knowledge of anticipated seepage losses is indispensible for successful design. With such information together with consumptive demand, estimated evaporation, and runoff patterns, the success of a proposed project can be reasonably predicted. The use of permeability investigations of the materials of small dams, and their reservoirs is suggested for all proposed small dam and charko construction on the reservation.

10-4.13 Minimizing Seepage. The greatest losses of water at the small dams and charkos of the reservation appear to be generally the seepage through the dam embankment or at its lower contact, and the percolation through the floor of the reservoir. The practical correction of excessive seepage is limited to three procedures, (1) compaction of native materials found at the site, (2) addition of fine-grained materials or particle expanding earths to site material, followed by compaction and (3) installation of impermeable films.

10-4.14 Minimizing Seepage by Compaction. Natural earth materials found near the ground surface are seldom found at their maximum density. When these materials are compacted to their greatest density, the volume of interstices are minimum and the material is then at maximum impermeability. Nearly all control of rolled fill dams is based on a moisture-density curve since earth materials are compacted to their greatest impermeability in presence of an optimum moisture content. Various methods are used to determine the optimum moisture content to assure maximum compaction in the field. Compaction of site materials used for fill, and compaction of the material existing on the reservoir floor is a method for reducing seepage losses.

10-4.15 Since it is impractical to determine compaction by counting passes of a roller, compaction requirements are usually checked with a penetrometer. This instrument measures the resistance of the fill to mechanical penetration, and can be correlated to permeability. The number of passes at which the reading becomes more less constant occurs when maximum impermeability for the soil at that moisture content is attained.

10-4.16 Moisture control on a generally permeable soil such as Dalles material is relatively simple. The TVA Manual for Earth Dam Construction reports (28, p. 28) it is practically impossible to apply too much water on fills of sandy and coarse texture.

10-4.17 Whether the permeable soils that are found at many of the plateau regions of the reservation can be compacted to acceptable limits for dam construction is not known. No permeability tests of compacted fill at the existing dams are known to exist.

10-4.18 Minimizing Seepage by Addition of Fine-Grained Material. Where site materials are so permeable that compaction alone is unsatisfactory, the addition of fine-grained materials mixed and compacted into the site material, or added intact and compacted as a separate layer may reduce seepage losses. The use of clay or other impermeable soil cores in earth dams is effective in sealing a dam. Where reservoir size is small the sealing of the reservoir floor may be practical.

10-4.19 Most fine-grained soils are capable of forming a seal. Clays are normally used because of their general common occurrence. However, the most abundant fine-grained material on the eastern portion of the reservation are the ashes of the John Day formation. The abundance with which the John Day ash appears over much of the reservation suggests its use as a core material in a small dam or as an ingredient to effectively seal the reservoir floor. The ash is reported by Abrams (1) to swell in the presence of moisture, a desirable characteristic for a sealant. It is not known if this material has been previously used for permeability control on the reservation. Discussions with residents indicate it has not.

10-4.20 Cement and bentonite is commonly used for effective treatment of seepage problems. While its use at the reservation would probably correct the seepage at both dam and reservoir, the use of available native material suggested in paragraph 10-4.19 appears to offer a more economical solution.

10-4.21 Minimizing Seepage by Installation of Impermeable Films. The use of thin impermeable films by installation of either flexible or rigid sheet material or by films formed by soil treatment, may be used to form an impermeable seal. Soil treatment films are usually associated with an asphalt cement, or bentonite treatment. A variety of cutoff sheet material is used. The rigid material such as sheet piling is usually associated with seals at dams larger than the type here discussed, and does not appear to have economic application to small stock water on the reservation. Recent improvements in plastic manufacturing processes have given increased acceptance to thin plastic films as a seal.

10-4.22 The use of black polyethylene for pond liners has gained increased acceptance due to recent improvements in quality and manufacturing processes permitting large sheet size. The use of plastic film as a seal at a dam and reservoir offers a barrier that practically eliminates all seepage. The availablility of black polyethylene film in seamless widths up to 40 feet wide, easily applied splicing tape, and a wide variety of gauges make it particularly adaptable to pond liners. Ames (15, p. 5) reports tests of polyethylene used at irrigation reservoirs in Coachella Valley, California to show no visible signs of deterioration after five years of full exposure to the elements. The greatest features attributed by manufacturers of this type of lining are its low cost, averaging around 10 cents per square yard installed, and an absolutely perfect seal that is apparently permanent as long as the plastic is protected. A perfect seal is easily obtained regardless of permeability of existing material.

10-4.23 Assuming an installed cost of 15 cents per square yard includes a 12 inch earth cover, the sealing cost of an acre of reservoir at the reservation would be approximately $650.00. This cost to secure a permanent seal that eliminates all seepage appears to be favorable.

10-4.24 The use of polyethylene films appears to have application to the seepage problems now existing at the small dams and charkos. A pilot trial at one or more of the existing sites now showing excessive seepage is recommended. The small dam on Miller Flat at location 8/11 - 22A is suggested as a possible trial site.

Section 10-5: Domestic Water from Surface Sources.

10-5.1 Sources of Water. Surface sources of domestic water are from irrigation units, ponds, or water pumped from perennial streams. The shallow wells adjacent to irrigation ditches yield water that is nearly identical to the water taken directly from the ditches. Existing objections to the use of surface waters for domestic purposes are directed toward sanitation deficiencies.

10-5.2 When a well or spring supply of water is not obtainable, a surface supply can be considered, but usually only as a last resort. Collection and storage will vary. In some cases, filtration or coagulation may be necessary, and in nearly all cases biological treatment is required.

10-5.3 Cisterns. The use of cisterns is an acceptable although usually not preferrable means of storing surface waters. The Farm Security Administration (12, p.3) suggests all cisterns are subject to pollution, however, there are times when it becomes necessary to construct cisterns. Cisterns should be made of concrete, brick or masonry. Metal is not recommended. Approved plans and construction instructions are available from various governmental agencies. Filtering is usually required, although filtering alone is not considered a safeguard against bacteria. The use of a cistern for domestic water requires chemical treatment or heat sterilization. Whether the installation of a cistern at a farmstead on the reservation offers the most practical source of domestic water depends upon availability of water from other sources.

10-5.4 Irrigation Ditches and Shallow Wells. Water taken directly from irrigation ditches, shallow wells near the ditches, or shallow wells near natural waterways or areas of effluent seepage is extensively used as domestic water on the reservation. Surface waters are generally abundant on Sidwalder Flat in the irrigation ditches, and nearby shallow wells that receive seepage from the ditches. Until ground water is developed, surface waters at Sidwalder Flat is the only available source of domestic water.

10-5.5 Water from all shallow wells or surface sources is suspect of pollution. Investigations by the Bureau of Indian Health, see Appendix IX-B, show that untreated surface waters used for domestic purposes on the reservation are invariably unsatisfactory. Shallow wells are naturally the most liable to pollution, but by careful construction and maintenance of sanitation standards their use for domestic purposes can be satisfactory. Biological treatment of the type described in section 10-6 is suggested however, regardless of other sanitation precautions taken.

10-5.6 At Sidwalder Flat the alternative to development of ground water by wells for domestic use is the use of adequate sanitation treatment of the generally available surface waters. Wells drilled to depths of 400 feet or less on Sidwalder Flat would probably deliver discharges adequate for farmstead requirements. The selection of surface waters as a source of domestic water depends upon several factors, the most important of the non-economic items being related to the sustained operation and maintenance of treatment facilities. A discussion of water treatment procedures applicable to rural use appears in Section 10-6.

10-5.7 Pumping from Perennial Streams. Schoolie Flat, the Island, Miller Flat, and Sidwalder Flat border perennial streams that offer a source of domestic water. Water from these sources would require a source of electrical energy at the pumping site, biological treatment, and an extensive distribution system to serve the scattered farmsteads. These streams, Mill Creek, Shitike Creek, Badger Creek, and Warm Springs River flow in deep canyons. Power requirements to lift water from the canyons would be large, but for the moderate pumping discharge required for a domestic system would constitute but a relatively small part of total cost.

10-5.8 An estimate for Surface Water System for Schoolie Flat. A plan for supplying surface water from Beaver Creek to a distribution line and reservoir serving Schoolie Flat is summarized below. The system as outlined below proposes serving the same area as the spring development described in paragraph 8-7.7. The essential features of the plan, which is plotted on a map Appendix IX-F.2, are a pumping site at Beaver Creek, a 4" buried steel pipe line up the east side of the Beaver Creek valley, a 4" buried transite pipe serving as a main line along the Simnasho-Hot Springs road and between the 4" steel pipe and a reservoir at the SE corner Sec.,3, T. 8S., R. 12E., and 2" buried steel feeder lines to points of delivery.

Physical description:

Area to be served	Schoolie Flat
Pump site	Beaver Creek, 8/12 - 7A
Elevation of pump site	2100 ft.
Anticipated number of farmsteads	40
Daily farmstead demand	1500 gal.
Total daily demand for system	60,000 gal.

Pipe Line:

Beaver Creek to plateau	4,500 ft.	4" steel.
End steel pipe to reservoir	13,000 ft.	4" transite.
Main line along Simnasho road	25,000 ft.	4" transite.
Feeder taps to residences	20,000 ft.	2" steel.
Design pump operating factor (8hr/day)	33%	
Required discharge of pump	125 gpm	
Reservoir location	8/12 - 3J	
Reservoir elevation	3,000 ft.	
Pumping elevation head	900 ft.	
Average pumping friction head per 1,000 ft. of main line	13 ft.	
Total pumping friction head	225 ft.	
Total pumping head	1,125 ft.	
Required pump hp, (75% hydraulic eff)	42 hp	

Estimated installed costs (Labor and material):

Power line construction	Included in hourly rate
Pump, motor, building, access (Includes standby unit)	$ 12,000.00
Electrical control system	5,000.00
Main line,	
4" x 4,500' steel @ $2.50	11,250.00
4" x 38,000' transite @ $2.00	76,000.00
2" x 20,000' steel @ $1.00	20,000.00
Reservoir, 80,000 gal. effective capacity, covered, chlorinator	9,000.00
Total estimated installed cost	$133,250.00

Estimated monthly operating costs:

Power, $0.015/kw. hr. (Includes power line construction and demand charges)	$ 120.00
System maintenance and repair (¼% installed cost	330.00
Monthly capital recovery at 5% for $133,250.00 investment having no salvage value at end of 40 years	645.00
Total estimated monthly operation cost	$1,095.00

10-5.9 On the basis of the above estimate, a surface water development for Schoolie Flat operating at a design capacity of forty homes would cost approximately $27.00 per month per home. An individual well drilled on Schoolie Flat having a depth of five hundred feet, fitted with pump and motor, would have an installed cost of approximately $4,000.00. Monthly operating costs including power, maintenance, repair capital recovery at 5% for the $1,000.00 pump and motor having no salvage value at end of 25 years, and 5% interest for well drilling is estimated in paragraph 9-4.10 as $22.00. The disadvantage of the surface water plan is the large investment required for the pipe line distribution system required at a sparsely inhabited area. Even with a design demand of 40 dwellings on Schoolie Flat, about two times that now existing, monthly charges per dwelling would be about $27.00. The advantage of the surface water plan is an assured sanitary supply of domestic water not subject to the uncertainties of well discharge.

10-5.10 In the event that demand for water on Schoolie Flat exceeds that outlined above, daily discharge could be doubled in the four inch main line by increasing pump size or increasing pump operating factor. If operating factor remains at approximately 33% and discharge is increased to 250 gallons per minute, friction loss in main line would increase approximately four fold. This amount of friction loss would mean a corresponding total monthly pumping cost of approximately $200.00. Pressure drop in the main trunk distribution line could be reduced by installation of a second reservoir at an elevation of approximately 3000 feet at location 7/12 - 27K, thereby providing parallel flow to and from each reservoir.

10-5.11 The disadvantage of a domestic surface water system for Schoolie Flat as outlined in paragraph 10-5.8, or of a ground water system as outlined in paragraph 9-8.15 (also see Appendix IX-F.1) is the improbability of a domestic demand under a dry land agricultural economy that is much larger than now exists. The high cost of the distribution system of either plan could be economically feasible only if the population on Schoolie Flat increases greatly, an unlikely occurrence without the construction of an irrigation unit on the Flat. The plan for pumping water from Beaver Creek, paragraph 10-5.8, is designed for forty homes, and at this demand would have little, if any, advantage over the anticipated success of individual or semi-individual farmstead wells. The ground water plan outlined in Appendix IX-F.1, having a design load of

150 families on the Island, Simnasho and vicinity, and Schoolie Flat, would have a monthly cost per family of approximately $23.00 per month, provided the plant operated at design capacity. See paragraph 9-8.16.

10-5.12 Because it appears unlikely that the population on Schoolie Flat will attain the size under a dry farming program approaching the design size of either system discussed in paragraph 10-5.11, and because the construction of an irrigation unit into the Flat would provide both the means of economically supporting an increased population and also provide a source of domestic water, the conclusion is reached that an extensive distribution system providing domestic water into Schoolie Flat is not advisable. See paragraph 9-8.17, 9-8.22.

10-5.13 An Estimate for a Stock Surface Water System for the Metolius Bench. Henderson (20) outlines a possible stock water supply system for the Metolius Bench area. Two separate plans are proposed, each pumping water through closed conduit from the Metolius River. The termination of each system is in the vicinity of Sec.11, T. 11S., R. 11 E. This report is presented in full at Appendix X-B, and IX-F.2.

10-5.14 The costs of either plan outlined appear to far exceed the benefits that can be derived. Water for stock in this area appears to be more economically obtained from spring development, wells, or from properly constructed small drainage dams.

10-5.15 Domestic Water at the Agency. As the population increases in the vicinity of the Agency, the dangers of contaminants entering Shitike Creek become more acute. Shitike Creek has a great value for both domestic water and irrigation. It has a well sustained discharge during the summer, the minimum daily observation being 32 cubic feet per second. Assistance in urban sanitation that is obtainable by Public Law 86-121, see paragraph 1-6.17, is encouraged.

10-5.16 Hydraulic Rams. Hydraulic rams offer a means of pumping surface waters where power heads of ten feet or more can be obtained by diversion and where delivery heads of generally 500 feet or less are required. A distinct advantage of rams is their use of hydraulic energy for driving power. The greater delivery heads require greater power heads for satisfactory operation. Rams do not appear practical for installations such as described in paragraph 10-5.8, due to excessive delivery heads. Nor would rams installed in series be practical at such a site because of excessive pipe sizes required at lower stages. One of the heavier rams manufactured by the Rife Ram and Pump Works, Model 40-A (50, p. 10) is reported capable of delivering 300 gallons per hour at a delivery head of 500 feet if a supply head of 50 feet supplies 80 gallons per minute to the ram.

10-5.17 The following table of hydraulic ram performance is given. Rams are available in a wide range of sizes to meet varying discharge requirements.

Table 10-5.17A

Normal Percentage of Supply Water Ram Will Pump at Varying Conditions of Supply and Delivery 1/

Power Head, feet	Total Delivery Head in Feet Above Ram, Including Friction.								
	20	40	80	100	150	200	250	300	350
5	13.0	7.8	3.6	2.6					
10	27.0	16.5	9.3	7.3	4.6	3.2			
20		34.0	20.0	16.0	10.5	7.7	6.0	4.8	3.8
40			40.0	34.0	22.4	16.4	12.8	10.3	8.1
60					34.4	25.8	20.2	16.0	13.0

1/ From Johnson Manufacturing Co., Inc. (27, p. 18)

Section 10-6: Water Treatment.

10-6.1 Need for Treatment. In general, a surface supply is not satisfactory for domestic purposes when used untreated unless the entire watershed is closed to humans and animals, a condition rarely, if ever, possible. Access by humans is usually more dangerous than by animals. The need for treatment of domestic water on the reservation, from both surface sources and ground water development, is indicated by the Bureau of Indian Health survey (69). See Appendix IX-B. No surface supplies are reported satisfactory, and approximately 50 percent of the spring and well supplies are reported as unsafe.

10-6.2 The reported dangerous condition of the domestic water on the reservation does not necessarily imply that those sources be discontinued. With properly designed biological treatment, water, from those sources now unsatisfactory can be made safe for human consumption. However, the ability of treatment procedures to kill disease producing organisms in water does not minimize the importance of reducing contamination at the source.

10-6.3 Treatment of water has particular application at the reservation because much of the domestic water is obtained from surface sources. water from the many shallow wells of the reservation and springs having effluent areas lying above the orifice are also suspect of pollution. From such sources there is little practical opportunity to remove entirely the chance of contamination. In such conditions, treatment is the only means available whereby these sources can be safely used.

10-6.4 Information Available. There has been much information, specifications, and recommendations published regarding treatment facilities for rural water supplies. Both federal and state health agencies, and state experiment stations have published manuals describing preventive measures to be taken to prevent pollution, and water treatment devices to correct pollution. Manufacturers that produce equipment applicable to treatment of rural water supply literature, and often trained technicians, to ensure correct use of their product.

10-6.5 Steps Involved in Treatment. The treatment program as followed in most rural water treatment installations of surface water requires three steps. The first step occurs in a settling basin to remove the larger sediments. Flocculation induced by a mechanical alum feeder may be used to help settle the particles in the water. The second step is a filtering process to remove the finer particles that did not settle. Water passing through two to four feet of fine sand is usually required. The last step is purification by chemical disinfection, although pasteurization may be used. Chlorine in a variety of forms may be used. The more commonly used are chlorine gas, chlorine salts, or commercially prepared solutions. Biological treatment by heat has been successfully used instead of chlorine.

10-6.6 Settlement and Filtering. Settlement of surface waters on the reservation is unlikely to require application of a flocculating agent. Settlement and filtration can be done in one divided concrete tank. The smaller compartment is a settling basin, the larger is the filtering chamber containing two to four feet of sand. The water filters downward through the sand. Although the action of sand filtering removes much of the disease producing bacteria, filtering alone is seldom, if ever, sufficient. At no installation on the reservation would treatment by filtering alone be advisable. Attempts to eliminate chlorination by filtering through greater distances of sand beds or attempts to re-filter are not practical.

10-6.7 A clear well that acts as a holding reservoir between filtration and chlorination is suggested to be located at a slightly lower elevation than the filtering tank. It may be of the same size as the filtering tank, in fact the same concrete forms may be used. Bulletins published by Kansas State College, described in bibliography numbers 29 and 30, are suggested as a guide for settlement and filtering tank construction.

10-6.8 Manual Chlorination and Manual Pasteurization. The simplest method of disinfection is by a manual batch treatment. If the quantity of water used each day is small, the batch treatment is satisfactory. Three methods are outlined by the Oregon State Board of Health (45, p. 17):

Method A: Boil the water briskly for a few minutes, allow to cool and store in a clean covered container. If the taste is flat, pour the water back and forth from one clean container to another to allow air to be absorbed. This is the simplest and safest method for treating small volumes of water.

Method B: Use ordinary household tincture of iodine (7%). For each gallon of clear water to be treated, add 5 drops of iodine. For muddy or mossy water, use 15 to 20 drops of iodine to each gallon of water. Then stir well and allow to stand for 30 minutes. At the end of that time the water should still have a distinct medicinal taste. If not, add more iodine. If the taste is too objectionable, it may be removed by adding a small crystal of photographic fixer or hypo (sodium thiosulfate). Do not add hypo until after the treated water has been allowed to stand for 30 minutes.

Method C: Use ordinary household bleach or chlorine disinfectant diluted to a strength of 1% available chlorine. Mix as instructions below:

Table 10-6.8 A

Disinfection of various quantities of water. (Use quantities below if water is clear and only moderately polluted. If water is muddy, mossy, or heavily contaminated use three times the amount of 1% chlorine solution indicated below.)

Volume of water to be sterilized.	Amount of 1% chlorine solution to be added.
1 gallon	5 drops
2 gallons	10 drops
5 gallons	25 drops
10 gallons	50 drops
50 gallons	6 teaspoonsful
100 gallons	6 teaspoonsful
500 gallons	9 tablespoonsful
1000 gallons	½ pint (1 cup)

10-6.9 A holding time of at least 30 minutes is suggested between iodine or chlorine treatment and time of use. The solution will lose its strength in a few weeks, so it must be made up frequently. Residual chlorine test kits are manufactured that are applicable to use by rural water treatment at the reservation. One is made by Wallace and Tiernan, Inc., referred to as Residual Chlorine Test Kit Type UXA-16007 (86). This kit, and others, consists of a pocket-sized color comparator, test tubes, indicator solution, and easy-to-follow instructions.

10-6.10 The batch methods of water treatment are safe and satisfactory, provided the recommended instructions are consistently followed. Their use at the reservation is at this time particularly applicable at areas not served by utility distributed electricity required to operate commercial automatic devices.

Table 10-6.8 B

Preparation of 1% Chlorine Solution from Various Chlorine Products.

Product	Form	% Available Chlorine, 1/	Amount to add to one gallon of water to make a 1% solution.
Purex	Solution	3% or 5%	5 1/2 cups or 3 1/4 cups
Clorox	Solution		
Hypro	Solution		
White Magic	Solution		
Nubora	Solution		
Sani Clor	Solution		
White Rose	Solution		
Master X	Solution		
Clor	Solution	15%	1 cup plus 4 teaspoons
Diversol	Powder	3%	3 pounds
HTH-15	Powder	15%	10 ounces
Chlorinated lime	Powder	25%	6 ounces (fresh)
B-K	Powder	50%	3 ounces
HTH-70	Powder	70%	2 ounces
Perchloron	Powder	70%	2 ounces

1/ The available chlorine in any of these products is subject to change by the manufacturer. The strength given on the label should be checked and solution adjusted accordingly.

10-6.11 Automatic Chlorination. To overcome the inconvenience of batch methods, automatic treatment devices are manufactured. These are simple in operation, practically trouble-free in maintenance, relatively inexpensive in both initial and operating cost, and capable of accurately metering chlorine at any rate desired. As a substitute to commercial units designed for small treatment operations, various schemes have been outlined for home-built chlorinators. The Oregon State Board of Health (45, p. 18) suggests two such systems that can be easily constructed, one an automatic suction-pump system, the other a constant-flow gravity system. The use of such home-made units at the reservation is not generally advised, unless extra precautions are taken in frequent testing of treated water for residual chlorine. Such devices do have the advantage of not requiring electricity for operation, a matter of considerable importance.

10-6.12 Most commercially manufactured units of the size applicable to farms meter a hypochlorite solution upon demand by a venturi or a small positive displacement pump. The solutions are of the type described in paragraph 10-6.8. The units are designed to function intermittently, as the water from the pump is admitted to the pressure storage tank. Nearly all require electricity, a requirement that at the present time precludes their use at most of the farms on the reservation. The cost of chlorinators varies, from approximately $75.00 to $300.00. No special knowledge is necessary to operate these units, the operator need only keep the solution container filled with hypochlorite solution, occasionally check an indicator dial to see at a glance if the feeder is operating properly, and periodically test the treated water to insure a required residual chlorine level.

10-6.13 The selection of chlorinators for use on the reservation should be influenced by the availability of repair service, replacement parts, etc. Wallace and Tiernan, Inc., maintain a branch at Portland, Oregon. This firm has in the past manufactured small belt-driven hypochlorinators for installations not having electric service. This A-537 Series (86, TP-30C-6) is reported (7) to be no longer in production due to infrequent demand for non-electric units. Water-motor driven units are so expensive, require hydraulic conditions generally not found on the reservation, and are more subject to mechanical failure. The Wallace and Tiernan Series A-415 (86, TP-30C-6), typical of most hydraulically operated units, costs about $500.00. Where electricity is available at the reservation, chlorinators similar to the Wallace and Tiernan Series A-588 or A-745 (86, TP-70-C-4) appear most practical.

10-6.14 Automatic Pasteurization. Automatic water treatment units utilizing pasteurization for farm systems have not been extensively marketed. Chlorination is the most common water disinfection process, but it presents problems of palatability due to excess residual chlorine. Since high chlorine residuals are unpalatable, there may be a temptation to operate at residual levels with small safety margins. Goldstein and others (16, p. 1) report that only a small percentage of such chlorinators have operated continuously and with sufficiently frequent measurement of chlorine residuals to assure adequate disinfection.

10-6.15 If chlorine residuals offering adequate safety margins appear to be objectionable to residents of the reservation, the use of automatic pasteurization may be desired. A pilot automatic pasteurizer designed for small water supplies has been tested at the Robert A. Taft Sanitary Engineering Center (16). The pilot unit is reported to treat polluted supplies containing 950,000 coliforms per 100 miles to conform with Public Health Service bacteriological standards. Capacity is sufficient to supply a family of five 90,000 gallons annually, at a treatment cost of $1.00 per 1000 gallons. The estimate is based on an electrical cost of one cent per kilowatt-hour and an annual amortization charge of 10 percent of the cost of the pasteurizer. Pasteurization is accomplished by electrical resistance heating requiring about 40 kilowatt hours per 1000 gallons of treated water. Much of the heat required to bring the water to pasteurization temperature is recovered through the use of a simple heat exchanger. The initial equipment is reported to be $520.00.

10-6.16 The application of such a unit at the present time is limited on the reservation to farms served by an electric utility. Although treatment cost is high compared to chemical disinfection, the advantages of improved palatability for an assured source of safe domestic water may outweigh the cost disadvantage. Drawings of the units and instructions for constructing the heat exchanger are available by addressing requests to the Director, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio.

10-6.17 Public Law 86-121. By authority of Public Law 86-121, enacted July 31, 1959, the Public Health Service, Division of Indian Health may work with residents of the reservation in the construction of sanitation facilities for their homes and communities. The legislation is intended to improve the health of the residents by creating a more sanitary environment which will reduce the amount of sickness from certain communicable diseases. Because many of these diseases are water borne, the correction of sanitation deficiencies is directly related to proper utilization of the water resource of the reservation. Public Law 86-121 authorizes the Public Health Service to cooperate both financially and administratively in the provision of sanitation facilities for Indian homes, communities and lands.

10-6.18 The provisions of this legislation can have a most favorable impact toward the health of the residents. To receive the greatest benefit from such assistance, it is suggested that all proposed development of wells, springs or surface waters of the reservation, whether developed privately or by the Bureau of Indian Affairs, be in accordance with sanitation provisions as suggested by the Public Health Service.

Section 10-7: Summary.

10-7.1 Records and Source of Data. A record of small dam construction on non-perennial waterways of the reservation, providing specification data, or performance is not known to exist. Most construction is located north of Shitike Creek and east of Boulder Corral.

10-7.2 Duty and Quality. The small dams and charkos have been constructed to serve primarily as a source of stock water in areas deficient of perennial surface water or ground water from springs and wells. When used for stock water, quality has not been a problem. Water in the ponds is not excessively turbid. The impounded surface water is probably slightly acidic.

10-7.3 Geographic Factors. Topography of the watershed on the plateau regions of the reservation is often quite flat or gently rolling. Except in those areas exposed by John Day ash the soil mantle is generally permeable. At the locations where small dams are desired, the water-table is nearly always deeply depressed and is overlain by a thick surface formation. The small amounts of annual precipitation occur mainly during the six winter months. The summer months are hot and dry. These four factors create runoff deficiencies, large seepage losses at both reservoir and dam, and considerable evaporation.

10-7.4 Minimizing Evaporation and Seepage. There appears to be no existing data of measurements of evaporation or seepage at reservoirs on the reservation. Evaporation losses during the six summer months probably approximate three feet. The greatest loss of water at the reservoir is probably due to percolation through the dam and through the reservoir floor. Determination of permeability coefficients of the material at the dam and reservoir is the only practical method of anticipating seepage. Accurate measurements of watershed runoffs are required to determine reservoir recharge capacity. Evaporation losses are more or less constant regardless of reservoir design, although the smaller reservoirs can be improved by reshaping to a deeper depth with less surface area. Seepage can be drastically reduced by proper compaction of reservoir floor and compaction of rolled fill at the dam. The use of clay or other impermeable borrow at the dam cores or reservoir floor reduces seepage. Where John Day ash formations are found within economical hauling distances, their use as a sealing core appears favorable. Recent improvements in manufacturing of polyethylene provides a relatively inexpensive barrier offering virtually water-tight construction. Plastic films appear to have application at the small dams or charkos where reservoir recharge is so limited that only a minimum of reservoir loss can be tolerated.

10-7.5 Domestic Water from Surface Sources. Surface sources of water on the reservation are irrigation ditches or nearby shallow wells, ponds, or perennial streams. All water from these sources is suspect of pollution, tests by the Bureau of Indian Health confirm their impurity. Their use is safe for domestic purposes only when properly treated. For developing large supplies of domestic water to serve the more populated rural areas such as Simnasho, water from a perennial stream, treated, and supplied through a distribution network appears to be nearly competitive cost-wise to ground water development from wells. Such a plan would be secure against the risk of inadequate ground water supply. A disadvantage is the high initial cost for the installation. The use of hydraulic rams at pumping sites has an advantage of requiring no electricity, however their hydraulic characteristics limit their use at the topography of the reservation.

10-7.6 Water Treatment. Small water supplies can be treated by either chemical disinfection or by pasteurization. Either type can be performed manually by a batch process, or automatically by continuous flow. The simplest method is by a manual batch treatment, although its inconvenience is a disadvantage. Both manual and automatic treatment utilize chemicals that are readily available. Because few farms on the reservation now have electrical utility service, the use of automatic systems, either chemical or pasteurization, do not have immediate application. The automatic systems are relatively inexpensive, are nearly trouble-free, and require but little attendance to operation and adjustment. For areas of the reservation having a general abundance of surface water from irrigation such as Sidwalder Flat, the use of batch chemical treatment of surface water offers the most inexpensive immediate source of satisfactory domestic water. Surface water stored throughout the year in a small dam is satisfactory source of supply to a treatment unit.

Section 10-8: Recommendations.

10-8.1 Watershed Runoff. It is suggested that watershed runoff investigations be made prior to construction of small dams or charkos on the reservation. Direct measurement of runoff, or estimate of runoff from a correlation of precipitation, topography, and permeability at the site is necessary to a sound approach to design.

10-8.2 Evaporation. A program of measuring evaporation at existing small reservoirs is recommended. Approved investigation procedures as outlined by either the United States Weather Bureau or United States Geological Survey are suggested. Results of this study should be considered in the design of all proposed small dams constructed on the reservation.

10-8.3 Permeability Coefficients. It is suggested that permeability coefficients be determined by approved testing procedures of all material to be used at proposed small dams, and at the reservoir floor. The selection of the site and materials should be consistent with anticipated losses of computed seepage determined from permeability tests. Permeability observations at the watershed are recommended to obtain correlation with topography, and precipitation patterns.

10-8.4 Inspection of Dam Construction. In so far as is practical with force account construction, inspection of rolled earth construction at all dam sites is suggested. Standards of compaction should be estalished prior to construction and be rigidly maintained during the entire job.

10-8.5 Permeability Correction by Cores or Films. Increased use of impermeable cores, either earth or films, at dams and small reservoirs is suggested. John Day ash, or clays, whichever is the more convenient, appears the most practical of the natural materials. Polyethylene films rolled in wide widths applicable for earth sealing, could probably be advantageously used for sealing problems at both dam and reservoir. Its advantage is the complete water-tight sealing regardless of degree of permeability of underlying or adjacent earth materials.

10-8.6 Treatment of Surface Water Used for Domestic Purposes. Where the anticipated cost of drilling a well is excessive or the uncertain success of the proposed well does not appear to justify its construction, the use of approved chemical disinfection of surface water is suggested. This recommendation at the present time has special application at Sidwalder Flat. The lack of electric utility service requires batch treatment, a method entirely satisfactory from a sanitation point of view, but somewhat inconvenient. Where electric utility service is available, automatic continuous flow hypochlorinators of reputable manufacture are recommended.

CHAPTER XI

IRRIGATION ON THE RESERVATION

Annual precipitation on the eastern portion of the reservation is between ten to twelve inches per year. Supplimental water by irrigation is required for successful farming. Construction of irrigation facilities began in 1936, and has continued periodically to this day. There are today six independent units in operation. Of the total of 1,286 acres now assessed, approximately one-third are being irrigated. There are 15,300 acres of land classified as I, II, or III. Of these lands, approximately 9,500 acres are in a position favorable for economic irrigation. The largest potential for irrigation lies on Schoolie Flat, an area containing slightly over 5,000 acres of irrigable land.

Section 11-1: History of Development.

11-1.1 Hincks. In December 1910, Mr. W. M. Hincks began surveys and investigations to determine the feasibility of irrigation on the reservation. The work, soon discontinued because of bad weather, was resumed in June 1911. During the summer of 1911, Mr. Hincks investigated both power and storage possibilities on the reservation and completed the irrigation survey of the Mill Creek Canal. Work was again temporarily suspended in November of 1911. During the summer of 1912, the survey was completed. Mr. Hincks submitted a report of his study on August 12, 1912 to Mr. Walter B. Hill, Acting Chief Engineer, U. S. Bureau of Indian Affairs. A copy of this report is said to be in the U. S. Department of Interior files in Seattle, Washington. Helland (19) reviewed Hincks' conclusions of water storage and hydro-electric potential in a report submitted in 1944. See paragraph 12-1.2.

11-1.2 Shitike and Tenino Ditch. From 1912 to 1935 there were apparently no irrigation investigations conducted on the reservation. However, during this time a small ditch was constructed, diverting water from Shitike Creek about one-half mile above the Warm Springs Agency. The ditch, known as Shitike Creek Ditch no. 1, was used to irrigate about thirty acres of school land south of the Agency. The work was reported to have been done by the school, and at school expense. Other small diversions from Shitike Creek and Tenino Creek were probably constructed during this time by the residents.

11-1.3 Hubbel, Norris, Holt. A report (57, p. 2) describes irrigation activity during the period beginning in 1935:

"Mr. J. J. Hubbel, Assistant Engineer, was transferred to Warm Springs, January 1, 1935, to assist on road work and to prepare plans and estimates for an irrigation system. An allotment of $1,000.00, I. I. R. R. 1935 Miscellaneous Projects, was made to cover his salary on irrigation work. On August 29, 1935, Mr. Hanna and Mr. Farmer visited the reservation and investigated several tracts for possible irrigation development. Mr. J. M. Norris, instrumentman, was detailed from Wapato and met Mr. Clotts at Warm Springs on December 8, 1935, at which time several possible projects on Mill and Badger Creeks, Warm Springs, River, Shitike Creek, and on the Deschutes River were investigated in a preliminary way. Surveys under Mr. Hubbel and Mr. Norris were continued. A preliminary report was submitted March 16, 1936 on the several sites. However, it was found that the area under Mill Creek had a very shallow soil, underlaid with cemented gravel and malapi, indicating that irrigation would be of doubtful benefit on account of the probability of swamping the land."

"About April 1936, Mr. W. E. Holt was sent to the Warm Springs Agency to take charge of irrigation work, Mr. Hubbel having been retired. He started construction on Shitike Creek Ditches nos. 2 and 3. Ditch no. 2, being one-half mile long, diverts water from Shitike Creek about one-half mile below the Agency, irrigating about thirty acres of Indian allotments. Diversion works consisted of a log dam with masonry wing-walls and a timber headgate. Floods in the spring of 1938 destroyed the dam. Shitike Ditch no. 3 diverts from Shitike Creek about one and one-half miles below the Agency to irrigate 110 acres. At the present time, 1939, about forty acres are irrigated. This ditch is about one and one-half miles long. The diversion works consist of a log dam and timber headgate, which are in good condition. The ditch has a small wooden flume 1,540 feet long, which carries water to a small tract along the Deschutes River. An allotment of $3,500.00 of E. C. W. funds had been made for clearing and leveling the Shitike tracts, and considerable progress had been made by September 9, 1936."

"An allotment of $10,000.00 from 'Construction, Indian Reservation (Reimbursible)' had been made for additional irrigation work on the Warm Springs Reservation for fiscal year 1937, and surveys were made by Mr. W. H. Farmer, beginning September 14, 1936. His report and estimate on the Mill Creek area were dated October 1, 1936. The estimate cost was $6,850.00. This report also mentioned the shallow soil and impervious sub-surface material."

<u>11-1.4</u> <u>Stevenson Soil Survey.</u> A soil survey by Stevenson (57, pp. 2-3) of approximately 1,000 acres of land on the then proposed Mill Creek unit is described:

"In order to confirm the conclusions in regard to soil conditions a soil survey of 1,000 acres of land, located in Sections 6 and 7, T. 8 S., R. 11 E., and Section 1, T. 8 S., R. 10 E. was made in December 1936 by R. E. Stevenson, Associate Soil Scientist, Oregon Agricultural Experiment Station. The report indicated that the area was not entirely satisfactory for the purposes intended, since nearly 50% of the area was eroded or partially so. Sheet erosion has removed good soil to a depth of two or three feet in many places, which altered the topography of the tract so that what was formerly a flat, gently sloping area is now a series of ridges with flats between. The eroded flats are from a few feet to two hundred feet wide, while the uneroded strips or ridges are usually wider. The report states that the surface soils not eroded, are silty loam to sandy loam in texture, dark in color, and a foot or more in depth. Structural development is good on areas not eroded to depths of three feet or more. Poor soil has been exposed where erosion was serious. The entire area is underlain by a cemented gravel layer which is quite impervious to water. This gravel layer is two to three and one-half feet under the surface where erosion has not taken place. . . . . The soils are about neutral or slightly alkaline in reaction. No alkali was found."

"The report stated that irrigation water should be applied sparingly in frequent, light irrigations because of the lack of capacity of shallow soils to absorb large quantities, and because heavy applications of water would result in water-logging the depressions. Provision should be made to remove, by means of surface ditches, surplus water resulting from precipitation or irrigation. The report recommended that irrigation should be attempted only on the better areas, where very little leveling is needed, and that adequate supervision in the application of water was very essential. Perennial forage crops, such as Indian clover, alsike, timothy, sweet clover, and alfalfa were recommended rather than cereals and annuals. Mr. Stevenson believed that there was a reasonable probability of success for a well-planned project on the area."

<u>11-1.5</u> <u>Construction of Mill Creek Unit.</u> Because of the importance of improved forage crop production on the reservation, construction of the Mill Creek Unit was began. Construction of this unit is described (57, p. 31):

"Mr. Hanna approved the construction of the project for the reason that production of forage crops was essential to carry the Indian cattle through the winter seasons, and thought it worth the experiment."

"Work was started by Mr. Holt on the Mill Creek Canal in May 1937. About 4,000 feet of the main canal and 1,000 feet of laterals were excavated with a power shovel borrowed from the Indian Roads Department. About one and one-half miles of canal were partly constructed by means of a grader and bulldozer. A log diversion dam, concrete headgate, two bridges, three concrete turnouts, one timber check and turnout, one timber check and spillway, three miles of drain ditches, and one mile of lateral ditch were built."

"On July 1, 1938, funds were made available under the following appropriations: Construction, etc., Irrigation Systems, Indian Reservations (Reimbursible) 1938-39, $15,000; 1938-40, O. P. 752-05-160, $25,000. . . . . On July 7, 1938, A. G. Lewis was transferred from the Flathead Reservation to take charge of irrigation work on the Warm Springs Reservation, superseding Mr. Holt who retired. Construction work, started in August 1938, was done with teams and hand labor, as there was no other equipment. Lateral 'A' was built to a point where water could be delivered to the Sidwalder Flats. Mill Creek Canal was enlarged for a distance of 9,000 feet and extended 3,000 feet. Considerable subjugation work and right-of-way clearing was done on the Mill

Creek Canal Unit. Five houses were moved, 58 acres of land were cleared and 75 acres of land were plowed."

11-1.6 Construction of Simnasho Unit. Construction of the Simnasho Irrigation Unit with its water storage at the Happy Valley Reservoir is discussed in reservation irrigation report (57, p. 3):

> "In 1937 the Soil Conservation Service in cooperation with the Civilian Conservation Corps and Bureau of Indian Affairs, started construction of a dam to conserve water for the Simnasho Unit. This unit comprises about 400 acres, but the area irrigated will be limited by the water available. This dam was completed in the spring of 1938. About one mile of lateral ditch and six wooden drops were built in 1937. . . In 1938 1,000 feet of drain ditch, two and one-half miles of main laterals, and some clearing were completed."

11-1.7 Construction on Shitike Creek. Irrigation construction in addition to that reported in paragraph 11-1.3 is reported (57, p. 4):

> "A new unit, known as Shitike Unit no. 4, was built on Shitike Creek about two miles above the Agency in 1938. The greater part of the area in this unit, about thirty acres, required clearing. In this same year Shitike Unit no. 1 was rebuilt, and a new diversion dam constructed to replace the one destroyed by high water. (See paragraph 11-1.3) Channel protection work was done on Shitike Unit no. 3, and the lower end of the ditch was rebuilt. . . . "

11-1.8 Helland. In 1944 Helland (19) submitted a report describing the hydro-electric resources of the reservation, and outlined briefly the possibility of a coordinated program of irrigation and power development. The full text of his report appears in Appendix XII-E.2. Because of the benefits of a coordinated power and irrigation development on the reservation, the contents of this report by Helland are discussed more fully in section 11-9, 11-14, 11-15, and paragraph 12-5.8.

11-1.9 Burch. In 1949, Mr. Burch completed a plane table survey of Dry Creek, Tenino Valley, Miller Flat, the Island, and Sidwalder Flat. The topography of the irrigable land is shown on the plane table sheets by one and two foot contour intervals. The plane table sheets are in the files of the Bureau of Indian Affairs, Irrigation Division, Portland. This field work was to be used in irrigation design of the areas surveyed. Except for the Tenino Valley Unit, finished maps or irrigation design are reported to be yet incomplete. In 1954, plans to construct the Tenino Valley Unit, see section 11-12, were abandoned due to lack of appropriated funds. The proposed construction of the irrigation for lands surveyed by Burch are reported to enable 6,500 acres of additional land to be brought into the Warm Springs Project, see paragraph 11-3.10.

11-1.10 Construction Since 1939. Construction on other units on the project include the Middle and Lower Warm Springs Unit, Deschutes

Unit, Tenino Unit (not to be confused with the proposed Tenino Unit described in section 11-12), and the Seekseequa Unit. All but the Deschutes and Seekseequa Unit are still functioning. The small annual appropriations continuing from year to year, together with the initial amounts allocated for investigations, surveys, and constructions have increased the total reimbursible funds due as liens against the project lands to a sum in excess of $300,000.00.

Section 11-2: Justification for Irrigation.

11-2.1 Climatology. In a climate where the annual precipitation is approximately twelve inches, occurring mostly during the winter months, dry farming is not profitable. The growing season, although short, is hot and arid. Irrigation must be developed if the Indians of the Warm Springs Reservation are to improve their economic status. The only portions of the reservation having favorable precipitation for dry farming lie in the steep slopes of the Cascades, in an area not topographically suited for cultivation. The great bulk of the reservation in the central and eastern part contains all the tillable land. Here the soil mantle is deficient in field moisture during the summer months, making irrigation a necessity for successful farming. A review of the climatology of the reservation is found in Chapter V.

11-2.2 Geology and Topography. The need for irrigation to supplement the meager precipitation is further increased by the geology and topography found in the central and eastern part of the reservation. Here the soils are often shallow, being underlain with basaltic rock. The ground water-table is deeply depressed because of the deeply eroded terrain. The result is a soil having a shallow root zone, that is deficient of moisture shortly after the spring rains cease. Dry farming is generally unsatisfactory.

11-2.3 Farming Patterns. The earlier studies regarding irrigation on the reservation, and the decision to commence construction was based on the recognized need to improve forage crop production. See paragraph 11-1.4. The project report of 1939 (57, p. 6) describes the justification of the irrigation units:

> ". . . . Irrigation must be developed. . . They have excellent grazing lands for perhaps four times as many cattle as they now possess, but due to lack of winter forage they are unable to utilize this grazing land to the full extent. It is planned, by means of irrigation to increase the winter feed supplies sufficiently so that the cattle herds of the Indians can be increased to the full capacity of the range lands. . . ."

11-2.4 Although it is assumed that the agricultural economy of the reservation will continue to be based primarily upon livestock and major consideration of the needs and requirements of irrigation is to be directed toward maintenance of forage resources, the economic feasibility of some of the potential irrigation development will require more extensive use than that from forage only. That is, the feasibility of an irrigation development for Schoolie Flat, having an estimated construction cost of over $400.00 per acre, (see section 11-13) would require crop revenues exceeding that possible from forage alone.

Section 11-3: Water Supply.

11-3.1 Source of Irrigation Water. Irrigating water on the reservation is generally limited to that received from surface sources. Only those wells located near perennial streams and penetrating recent sedimentary alluvium are likely to have discharges of sufficient magnitude for field crop irrigation. However, at these locations, pumping directly from the stream is available and would have greater economy. Except for small garden plots, ground water from either springs or wells is of inadequate supply for irrigation. The plateau lands of the reservation are so high above the adjacent perennial streams that pumping or irrigation water in these locations is generally economically prohibitive. McGuinness (31, p. 61) describes pumping of water from depths exceeding 500 feet to be favorable only for irrigating valuable crops enjoying a good market price.

11-3.2 All the surface water flowing in the perennial streams of the reservation are eventually tributary to the Deschutes River. The major streams of the reservation, the Warm Springs River, Shitike Creek, Mill Creek, and the Whitewater River all have their headwaters in the Cascade Range. Their sustained flow is due to snow and glacier melt, and to effluent seepage from the annually recharged lavas at the high elevations in the Cascades.

11-3.3 Drainage and Topography. Topographically, the streams of the reservation are favorably situated for supplying water to irrigation units. All the major streams flow in a generally easterly direction across the reservation. Although the streams appear to be effluent throughout much of their course, they receive most of the waters at sufficiently high elevations to permit diversion and gravity distribution to much of the tillable land of the reservation. The major exception to this is the potential for irrigation on Schoolie Flat. The irrigable land on this plateau lies above any practical point of diversion and above the land over which the diversion canal must cross. Irrigation for such terrain requires pumping.

11-3.4 A serious limitation to the feasibility of irrigation on the reservation is the widely scattered locations of relatively small plots of irrigable lands. The irrigable lands are restricted to generally small tracts on plateaus bounded by deeply cut canyons, or to small and narrow tracts isolated on the valley floor. Within an irrigable tract, considerable amount of unirrigable lands are often found. Such terrain requires long canal and ditch systems, often constructed at great expense to traverse the uneven and rocky terrain.

11-3.5 Discharge of Streams. Discharge measurements of the streams of the reservation are submitted in appendices of Chapter VI. Data for the Warm Springs River is more complete than for any of the other streams that flow across the reservation. In general, discharge measuring stations have been downstream from potential diversion or storage sites. A few miscellaneous readings at scattered stream stations provide some basis for estimating discharge at the high elevations. There are at the present time no stream gaging stations being continuously observed. It is suggested that a stream gaging station program be made in cooperation with the U. S. Geological Survey. See paragraph 6-5.1.

11-3.6 With the exception of the Simnasho, Seekseequa and Tenino Units, a shortage of water at the stream diversion point has not been a problem at the existing units. Although stream discharge is minimum during the late summer, it is sufficiently sustained to provide adequate supplies of water to the Mill Creek, Middle and Lower Warm Springs River, and Shitike Creek units. With storage sites available on the reservation, and with proper disposition of available water, irrigation can be considerably increased over that of the present project. The need for further stream discharge data arises if a coordinated use of surface waters for both irrigation and power is to be considered. A brief review of the stream discharge patterns, taken from Chapter VI is given:

Table 11-3.6A

Discharge Summary of Streams

Stream	Location	Average annual runoff, ac.-ft.	Month of average minimum discharge	Amount of average minimum monthly discharge, cfs.	Amount of average discharge May to Aug. incl., cfs.
Warm Sp. R.	Hehe Mill	134,000	Sept.	121	185
Warm Sp. R.	Simnasho bridge	334,000	Oct.	277	460
Shitike Ck.	mouth	77,300	Sept.	61	120
Whitewater R.	mouth	76,800	Oct.	58	155
Mill Ck.	Olallie L.	7,600	Oct.	negligible	13
Mill Ck.1/	Old Mill	48,500	Sept.	38	74

1/ Estimated by computing discharge ratio of 0.62 with Shitike Creek. See Table 11-10.5A, 11-10.5B.

11-3.7 Irrigation Water Quality. The quality of the surface water of the reservation is excellent for irrigation. There are no salts or other minerals found in the water in quantities to be detrimental to plant growth. Water quality is further discussed in section 6-3.

11-3.8 Storage. Analysis of the discharge patterns of the streams of the reservation show that they have a relatively uniform flow throughout the year. This is a distinct advantage for this area, that has relatively few reservoir sites on its streams. The uniform gradient of the streams and general lack of impounding sites suggest canals fed by stream diversion. There are two storage sites that appear to benefit the irrigation potential of the reservation.

11-3.9 The first, a potential storage site on the Warm Springs River, exists at Schoolie Pasture. The topography is ideal for both the impounding structure and the reservoir. A description of this site appears in several reports. Helland (19), in his report of a hydro-electric potential and in a review of Hincks' report describes the site. A copy of Helland's report appears in Appendix XII-E.2, with a map at XII-F. The site is described as having a capacity of approximately 100,000 acre-feet. A dam approximately 125 feet in height and having a crest length of about 600 feet would back water up about three miles upstream, flooding the broad flat of the Schoolie Pasture to an elevation of 2,825 feet above sea level. Existing discharge measurements on the river near the Hehe Mill indicate that such a reservoir could be filled annually.

11-3.10 The Schoolie Pasture site is indicated as a potential storage site in various federal inventories of water resources of the northwest. In each instance, with the exception of the Helland report, the site is tabulated as serving irrigation only. The U. S. Corps of Engineers, Portland, Oregon, in a report submitted October 1948 (61, chap. IV, p. 379), lists the reservoir capacity as approximately 100,000 acre-feet to serve irrigation. In 1951, the Corps submitted a report on the resources of the Columbia River (62, para. 396, p. 2409) describing the proposed Schoolie Pasture reservoir as being able to bring 4,000 acres of new land under irrigation, and to supplement water to 1,500 acres reportedly then under existing units. The report reads:

"The Bureau of Indian Affairs estimates that a total of 12,000 acres of land on the Warm Springs Indian Reservation is suitable for irrigation. Under an authorized continuing project, the Bureau of Indian Affairs proposes a 6,500 acre increase in the number of existing irrigated areas by additional diversions and possibly by providing storage. A possible future storage project, considered by the Corps of Engineers to serve these and additional lands could be constructed at the Schoolie site near the headwaters of the Warm Springs River. At this point the river passes from a broad meadow into a canyon, and a dam to raise the water surface 92 feet would create a reservoir estimated to impound a total of 100,000 acre-feet. The drainage area above this site is 95 square miles, and estimated average annual run-off is about 110,000 acre feet. Storage made available at this site would be sufficient to irrigate all irrigable lands of the

Warm Springs Reservation, but further study would be required to determine whether some of the same lands, because of scatter locations, could be irrigated more economically by direct diversion from other streams on the reservation."

11-3.11 Investigations of the Schoolie Pasture site have been to this date limited to preliminary reconnaisance. There has been no geologic study made of the dam site. The site is underlain with basaltic formations, a material often not favorable for impounding structures. Stream discharge data has been sufficiently extensive on the Warm Springs River in the vicinity of the site to give reasonable credence to reservoir recharge estimates.

11-3.12 A second potential site for storage of irrigation water exists at the chain of lakes south of Olallie Butte. An eighteen or twenty foot high dam at the outlet of Trout Lake, a five foot high dam at the outlets of both the Island Lake and Dark Lake would provide an inexpensive method of impounding water at the headwaters of Mill Creek. The increased capacity at these three lakes gained by the installation of the small checks at the lake outlets would provide a net storage of approximately 2,000 acre-feet. This water released in the channel of Mill Creek would serve to supply the extended Mill Creek Unit. Although the Bureau of Indian Affairs have tentative plans for using this water to supply regulation to Mill Creek for irrigation into Miller Flat and Dry Creek, it does not appear that sufficient water would be available from this source. See section 11-11. The results of the recent soil survey indicate that there are insufficient irrigable lands in Miller Flat and Dry Creek to warrant canal construction. See section 11-9.

11-3.13 A third storage site on the reservation appears to have value solely as a power site, its value to irrigation being little, if any. This is the Hot Springs site, outlined by Helland (19) and described in Appendix XII-E.2 and XII-F. Although 10,000 acre-feet could be impounded, the topography of the site is such that the value of the water could be more advantageously directed toward power development.

11-3.14 Waste or Seepage Return. There is at the present time no data available regarding the amount of irrigation water on the reservation that re-enters either the ground water zone or the perennial water-ways. Personnel of the Agency Land Operations Office are of the opinion that nearly all return is from wasteways, and that deep percolation from the irrigated fields is now negligible. This appears probable, for irrigation on the reservation has not been extensive.

11-3.15 In general, waste or seepage return on the reservation at existing or future irrigation units would be at such low elevations to have little value for irrigation. Such re-use would be limited to irrigation on the lower Warm Springs River or lower Shitike Creek. The principle benefit of irrigation water return to be enjoyed by the residents would appear to be from the occurrence of ground water mounds in areas of extensive irrigation. See paragraph 2-7.10. The topography and geology of the plateau lands of the reservation probably would not permit the water-table to rise to heights creating an agricultural problem, but would elevate the water-table sufficiently to improve well performance.

11-3.16 Return water returns gradually and uniformly throughout the year. It does not return to the river directly, but first joins the ground water in the porous sub-surface formations. Henshaw (22, p. 75, 90) suggests that 50% of the water diverted into the irrigation unit above Benham Falls is available for re-use below. This is probably a reasonable estimate for total water return from canal seepage and system loss in areas of extensive future irrigation on the reservation. Henshaw reports:

"Though it is impossible to predict with certainty the time or amount of return seepage from an extensive irrigation project such as is possible in the central part of the Deschutes basin, it is believed that the fullest use of the upper Deschutes River for irrigation will not seriously impair possibilities for power development on the lower river, and in fact may even be a benefit, as a part of the return water will doubtless reach the river during the winter months, which usually constitute the low water season."

11-3.17 Canal Losses. Canals serving existing or proposed irrigable lands on the reservation must traverse areas outcropped with permeable basaltic material. Considerable loss of water due to seepage from such unlined canals can be expected. Henshaw (22, p. 89) suggests 30% as a probable loss between point of diversion and point of delivery for a canal of moderate length. Israelson (25, p. 69) reports an average of 38% for canal loss from irrigation canals in 17 western states.

11-3.18 The most certain method of obtaining reliable seepage loss measurements from existing canals is to subtract total turnout discharge from inflow. A pool built in a long section of the canal to be tested allows seepage rate to be directly measured. In some short sections of existing canals, the loss may be significant, but yet too small to measure by direct inflow-outflow measurement. Seepage from proposed canals can only be approximated by determining the permeability of the canal bed and bank materials, the wetted perimeter, and the hydraulic slopes causing seepage.

11-3.19 Canal losses for proposed units on the reservation will probably be between 25% to 40%. The greatest losses will be anticipated where canals are constructed from materials containing large percentages of basalt. The most inexpensive overall effective method of reducing canal losses is the use of approved rolled earth construction. See paragraph 10-4.14. The use of additives is expensive, but sometimes necessary when compaction methods alone will not provide a seal. Bentonite, clays, and ash are some of the suggested earth additives.

11-3.20 Water Rights. There has been no water right procedure initiated on the reservation. Although the failure to file water rights or establish a code of rights has not in the past constituted an obstacle in the use of surface water, an adoption of a code of water rights is suggested. Regardless of the character of future utilization of surface waters on the reservation, their use will undoubtedly increase to an extent where infringements will become common if water use is unregulated. The problems of water appropriation are more easily solved if a water right code is established prior to extensive use.

11-3.21 The project report of 1939 (57, p. 4) describes the water interest of the streams of the reservation:

> "As all streams head on the reservation and flow into the Deschutes River on the reservation, there are no outside interests in the water . . . . "

11-3.22 This description of the origin of these streams is not entirely correct, for both the Warm Springs River and Mill Creek receive waters from outside the boundary of the reservation. These outside interests, however, now lie within federal owned lands, and are unlikely to present a conflict to the use of these waters.

Section 11-4: Description of Existing Units.

11-4.1 General Statement. The entire Warm Springs Project is composed of eight small individual units, six being in operation at the present time. Agency records (73, p. 5) report in 1939 a total of 5,700 acres were proposed to be served by these systems and by their extensions. The total extent of assessed acreage has never exceeded 1,300 acres. At the present time 1,286 acres are assessed. During the years of operation the amount of land actually irrigated has varied from 25 to 40 percent of assessed acreage.

11-4.2 With the exception of the Simnasho unit, all receive water from unregulated stream diversion. Water storage has been constructed for only the Simnasho unit. The shortage of water has been critical at three of the eight units. A map showing the location of the eight units, comprising the existing and former systems, is shown in Appendix XI-A. The Bureau of Indian Affairs have detailed maps (74) showing each unit, the maps being available in Agency records. Land classification data of the existing units appear in the feasibility report (56) of 1958, and also in the recent soil survey conducted by the Bureau of Indian Affairs during 1959 and 1960.

11-4.3 Mill Creek Unit. The Mill Creek Unit is located on Sidwalder Flat, and is entirely north of Mill Creek. Water for the unit is obtained from unregulated diversion from Mill Creek near the Old Mill Ranger Station. The estimated average minimum discharge of Mill Creek at the diversion turnout during the irrigating season is approximately 40 cubic feet per second. Sufficient water has been available at the turnout for irrigation of existing irrigated lands.

11-4.4 The main canal, having a total length of about eight miles, passes around the south end of Sidwalder Butte. This is the largest unit on the reservation, from both standpoint of acreage assessed and acreage irrigated, and from the standpoint of length of constructed canal. Seepage losses from the main canal are not known, but are estimated to be 25 to 30 percent of diverted water.

11-4.5 The soils of the unit tend to be heavy and shallow, a condition that will cause increased drainage problems as irrigation becomes more extensive. Most of the land is reported (56, p. 34) to be class III, although the recent soil survey reports that 75 percent of the irrigable lands of Sidwalder Flat are of class II. See Appendix XI-D.1. Irrigation on the unit is difficult because of the many small waterways and other irregularities of both soil and topography.

11-4.6 The total amount of lands irrigated during 1938, the year following initial construction, is reported (57, p. 5) to have been 72 acres. In 1939, irrigated acreage is reported (73, p. 48) to have increased to 416, and in 1940 about 500 acres were being irrigated. Since that time the amount of land actually irrigated on the unit has varied from year to year. Today there are 842 acres assessed on the unit. In 1958 and 1959, the irrigated acreage of 26 tracts was 415 and 272, respectively. An inventory of 1943 (73) reports an ultimate potential of the expanded Mill Creek unit as being approximately 4,000 acres. Results of the recent soil survey indicate that the combined total of irrigable lands on Sidwalder Flat, Miller Flat and Dry Creek do not approach 4,000 acres. See Appendix XI-D.1.

11-4.7 Simnasho Unit. The Simnasho unit is located in Quartz Creek Valley, near Simnasho. Water for the unit is supplied from an earth dam on Quartz Creek. The reservoir has a capacity of 386 acre-feet, and is the only existing irrigation water storage on the project. A ditch system having a total length of two and one-half miles has been constructed. The most serious problem now existing for the full development of irrigation at Simnasho is the lack of water. There are no known discharge measurements for Quartz Creek, however, it is reported (56, p. 16) that water available from the existing storage on Quartz Creek is sufficient for irrigating approximately 140 acres annually. In view of the limited capacity of the Happy Valley reservoir, and its small watershed of approximately 7,500 acres lying in a low rainfall region, it is unlikely that satisfactory irrigation is possible for acreages exceeding 70 to 80.

11-4.8 The soils of the unit are reported (56, p. 16) to be mostly class II. The recent soil survey reported the irrigable soils to be mostly class III. See Table 11-13.7 A. The valley land in this unit is poorly drained.

11-4.9 Records indicate that shortly after construction of the unit, irrigation was extensive. A report of 1941 (73, p. 48) indicates that during the years 1939 and 1940 a total of 135 acres and 200 acres, respectively, were irrigated. The amount of water applied is not known. The total potential for the unit is reported by the Irrigation Division (74) in 1943 to be 391 acres. In 1958, 183 acres were removed from the unit, leaving 40 acres of assessed land. During 1958 and 1959 only 21 acres were irrigated. The reservoir is now used for growing fish.

11-4.10 Shitike Creek Unit. There have been several diversion structures constructed on Shitike Creek which have served small independent systems. See paragraphs 11-1.3 and 11-1.7. Shitike Creek flows on a uniform gradient, and has a discharge that is well sustained during the summer months. Irrigation by unregulated diversion is satisfactory. Minimum flow occurs during September, being slightly above 60 cubic feet per second. It is an excellent source of irrigating water for the valley soils of both lower Shitike Creek and Lower Tenino Creek. Water supply is not a problem. The four previously constructed unregulated diversions constructed on Shitike Creek are tabulated:

Table 11-4.10A Shitike Diversions. 1/

Ditch No.	Diversion Location	Ditch Length	Irrigated Acreage
1	½ mi. above Agency	½ mi.	30
2	½ mi. below Agency	½ mi.	35
3	1½ mi. below Agency	1½ mi.	110
4	2 mi. above Agency	Not known	30

1/ From (57, p. 4)

11-4.11 Soils in the Shitike system are deep and of medium texture. The land now being assessed contains about one-half class I, one-sixth class II and one-third class III.

11-4.12 The total of irrigable lands of the four systems described in 1939 was 205 acres. In 1943 the Irrigation Division reported (74) a total irrigable acreage of 175, with an additional 314 being temporarily non-irrigable. Irrigation from the Shitike systems has decreased considerably in recent years. In 1939 and 1940 a total of 90 and 165 acres, respectively, were reported as being irrigated. The Shitike Creek unit today contains 70 acres of assessed land.

11-4.13 Tenino Unit. The Tenino unit, located in Lower Tenino Valley, has consisted of three diversions from Tenino Creek and one from Shitike Creek. One of the Tenino diversions is not now being used. The greatest source of water for the Tenino unit is from the Shitike diversion, Tenino Creek being dry during late summer months.

11-4.14 A report of 1941 (73, p. 38) describes ten acres as being irrigated annually from Tenino Creek, and that the limited natural flow prevents further expansion of that source of water. At the present time

38 acres are being assessed, and slightly less than one-half of that being irrigated. The Irrigation Division in 1943 reported (74) 151 ultimately irrigable acres within the system. The soils of the unit are deep with a medium texture.

11-4.15 Middle Warm Springs Unit. This unit is located in the Warm Springs River between Hot Springs and the Lower Warm Springs Road. A concrete diversion three-fourths of a mile below the bridge supplies water to this system and a secondary system, the Lower Warm Springs Unit. Two hundred six acres are assessed as irrigable in the system. During 1951, 87 acres were irrigated. The soils of the unit are mostly deep and of Class II and III. Soil texture is variable, with the lighter soils being on the north side of the river.

11-4.16 Lower Warm Springs Unit. The Lower Warm Springs Unit receives its water from two diversions. The major structures are two crossings, a 20 inch by 800 feet steel siphon, and a 12 inch overhead crossing. The 90 acres of assessable acreage lie at the mouth of the Warm Springs River, and extend down the Deschutes River. Soils are up to 60 inches deep, and are of Class II and III.

11-4.17 The unit has not been extensively used. In 1958 only 20 acres were irrigated. A washout of the main canal in 1959 prevented any irrigation from the unit. Water supply for both units from the Warm Springs River has been adequate.

11-4.18 Deschutes Unit. The Deschutes Unit consisted of two pumping sites that supplied water to 33 acres located a short distance downstream from the existing re-regulating dam of the Pelton dam. Irrigation maps (74, WS6) indicate approximately one-half mile of ditch to have been constructed. The pumps have been removed, and the unit is no longer in operation. An existing turnout at the re-regulating dam can furnish water to a portion of the area formerly served by the pumps.

11-4.19 Seekseequa Unit. The Seekseequa Unit consisted of unregulated diversion from Seekseequa Creek to approximately eight acres of allotment No. 281. The unit was not successful because of inadequate water supply. It is not now in operation.

Section 11-5: Operation of Existing Units.

11-5.1 Physical Condition of the Project. The canals and water control structures of the project are in a poorly maintained condition. Many of the canals of the project do not have the capacity to carry the amount of water required for satisfactory irrigation methods. The inadequate canal and ditch capacity appears to be a result of both initial design and construction, but also due to accumulated silting and weed growth that now retards flow. Forcing water through the poorly maintained canals has the inevitable effect of causing failures during the irrigation season. Canal failures, such as that occurring at the Lower Warm Srrings canal during the irrigating season of 1959, mean expensive but often poorly constructed emergency repairs. During a period of such emergency repairs the water user suffers loss of his crop.

11-5.2 Much of the original construction was apparently of temporary construction. Operation during the following years has required periodic addition of checks, turnouts, etc., that are necessary to the system, but were originally temporary or non-existent. Many of the old wooden structures have still not been replaced. Some of the land originally classified as irrigable were assessed, even though irrigation was impossible. During the years some of these assessed lands have been removed from the system, but it appears that there still remains considerable land in the project that cannot be irrigated.

11-5.3 Land leveling practices have not been satisfactory on the project. Some lands that have been leveled are still in disuse, either because of uncovering of sterile sub-soil, poor gradients, or because of improper irrigating methods. The subject of land leveling is treated in greater detail in Section 11-8.

11-5.4 Economic Problems. During the approximate 20 years that the various units have been in operation, the use of the irrigation facilities by the water users has not been encouraging. A tabulation of use of the project for the last 10 years, and a unit tabulation for the last two years is given:

Table 11-5.4A Irrigated Acreage in Project. 1/

Year	Total Assessed Acreage	Total Irrigated Acreage
1950	1,300	746
1951	1,300	692
1952	1,300	468
1953	1,300	494
1954	1,300	484
1955	1,300	404
1956	1,286	233
1957	1,286	282
1958	1,286	651
1959	1,286	437

1/ From Annual Irrigation Crop Report and Water User's log, Irrigation Section, Agency Land Operations.

Table 11-5.4B Irrigated Acreage in Units, 1958-59.

Unit	No. of Irrigable Tracts	Assessed Acreage	Irrigated Acreage 1958	Irrigated Acreage 1959
Mill Creek	26	842	415	272
Simnasho	1	40	21	35
Middle Wm. Sp.	6	206	167	87
Lower Wm. Sp.	3	90	20	0 2/
Tenino	4	38	0	16
Shitike	7	70	28	27
TOTAL		1,286	651	437

2/ Canal failure, system inoperative during the irrigating season.

11-5.5 An economic and feasibility report (56, pp. 1-6) of 1958 describes the economic problems of the projects:

"Each of the six active units have problems unique only to themselves; while at the same time, there are problems common to all the units. There are but a few farms within the units on the Warm Springs Reservation irrespective of management that can be farmed economically at the present time. The major reason for this condition is the small size of the farm units and the diversity of ownership patterns. The majority of the lands under the projects are leased or assigned."

"In addition to being too small, the individual fields within each farm unit are small, irregular in shape, and often separated by rock outcroppings. Much of the land is marginal or sub-marginal for agricultural purposes. This is especially true on Mill Creek and Lower Warm Springs Units. The farms are located at considerable distance from market outlets. The roads over which this produce must travel are being maintained in fair condition, but during the spring travel to some areas becomes uncertain. Distance to market is not as important a factor as it was many years ago. However, these costs add to the overhead on these projects and must come from an income already considerably inadequate."

"There are several factors responsible for the decrease in irrigation activity on the projects, such as climate, soils, position, distance to market, education, off the farm income and others . . . . The majority of the income for the residents comes from off the farm sources. There are instances where the outside income is used to subsidize the farming operation."

"The reasons are many and complex. To mention a few, easy access to off the farm income, an inherent desire to travel, gregariousness (a virtue if not allowed to dominate their lives), need for educational media in the field of general and irrigation agriculture, and apathy toward successful agriculture on the part of many who control the agricultural area on the reservation. There is an increasing tendency for the farmers to live in small communities near the periphery of the Agency in the winter time and move back to work the land during the summer month . . ."

11-5.6 Operational Problems. The eight former units, or the six now functioning, are widely dispersed on the reservation. The irrigable lands within the units are often irregular in shape and widely separated from each other by rough and irregular terrain. These systems usually require considerable lengths of canal construction to serve relatively small acreages. When the canal system must traverse rough terrain, the cost of initial construction and the troublesome problems of maintenance cause the feasibility of that unit to be questioned. To properly maintain the existing project requires transporting of equipment back and forth between the various units. When an independent unit is little used there is always a tendency for maintenance to be delayed until the unit is inoperative.

11-5.7 Canal erosion has been a problem on the reservation, and will continue to be so on the hill-side canals. Erosion from the ash cliff south of the Shitike Creek diversion will continue to contribute to high maintenance charges until the canal is relocated or protected by conduit. Spillway sections on the Mill Creek main canal to handle storm flow off Sidwalder Butte are suggested as a means of preventing overtopping and canal failure during the spring storms.

11-5.8 Much of the project lies upon materials containing large amounts of basalt. Where canals are made from such materials, it can be expected that heavy loss by seepage will occur. There are apparently no canal measurements available to determine the amount of seepage occurring at the various units. Seepage has not appeared to have been a serious problem on the existing units. However, if water consumption increases on the present facilities, or if the existing units are extended to utilize the entire surface water supply, then the extent of canal loss will become important. This would be a problem in the expanded Mill Creek Unit described in Section 11-11.

11-5.9 The weed and plant growth that has been allowed to infest the canals throughout the project are the greatest contributing cause for poor canal capacity. The willows that have become established on the Mill Creek canal have reached a size where canal cleaning becomes increasingly costly. Aquatic grasses in many of the laterals now make it impossible for a water user to receive an adequate head of water.

11-5.10 Plant growth in the canals, particularly at the Mill Creek Unit, is partly attributed to the usual practice of allowing water to remain in the canal nearly the year round to supply stock water to Sidwalder Flat. The availability of surface water for stock could be as satisfactorily met by construction of holding ponds, filled by the ditch. A properly constructed pond could hold water throughout the time the ditch is normally shut down. Allowing the ditch to be dry during the time irrigation is not required would reduce weed growth, silting problems, and structure damage during winter months. During the past few years considerable improvements have been made in chemical methods of aquatic weed removal. For a project such as the Warm Springs Project, which operates with a minimum of maintenance personnel and equipment, the use of chemical weed removal may have useful application.

11-5.11 The temporary wooden structures that were installed during the period of initial construction are being gradually replaced. A program for project rehabilitation, see paragraph 11-6.5, proposes the erection of improved diversion structures, checks, and turnouts on the six functioning units.

11-5.12 The source of irrigating water, with the exception of that to the Simnasho Unit, comes from unregulated stream diversion. Such a source can present problems of water supply during the late summer when natural stream discharge is minimum. This is a problem at the Tenino Unit which receives its water from a stream which is dry during the latter part of the irrigating season. It has not been a problem on the Mill Creek Unit, due to the lack of extensive irrigation by water users, but in the event the unit becomes more extensively irrigated, rigid control of the available water would then become necessary.

11-5.13 Problems of the Water User. There are many problems confronted by the water user on the project that discourage the use of the present facilities, or have prevented its use entirely. The general inadequate capacity of most of the present canals and ditches make it impossible for the water user to satisfactorily irrigate his land. A re-survey is required to remove from the project lands which cannot be irrigated, but which are now assessed. There are Class IV lands included in the present assessed acreage, a soil classification that is usually not suited for irrigation. The inability to obtain water at sufficiently large heads to permit satisfactory irrigation methods discourages the water user to irrigate lands which may be otherwise irrigable. Low application rates extended over an excessive length of time do not permit adequate attendance of the irrigator. It contributes to poor irrigation of the crop, inefficient use of water, and discouragement to the water user. Most of the soils of the project are of medium texture and relatively shallow. Light applications are necessary, the light applications require adequate heads to quickly force the water across the field with a minimum of percolation.

11-5.14 The general poor control of water on the project does not permit water delivery at the time needed. Emergency repairs during the growing season that require the ditch to be closed mean partial or complete loss of the crop. Failure for ditch repairs to be made during the time the system is normally inoperative prevents its use during the early part of the irrigating season.

11-5.15 There seems to be a sincere desire by the water users to obtain information of irrigation methods and use more fully the facilities of the project. The inability to satisfactorily irrigate a crop is often directed toward the mismanagement of the canal systems. Management and engineering personnel of the irrigation project attribute the poor condition of the project to the apathy of the water users. Such an impasse can not continue if the project is to succeed. There is an immediate need to rehabilitate the project to satisfactory standards of performance, and to provide the closest possible coordination between system operation and the needs of the water user. Assistance in irrigation methods and procedures should be available to water users. Irrigation methods and land leveling procedures as applied to the reservation are discussed in sections 11-7 and 11-8.

11-5.16 During 1960, a questionnaire distributed to the residents as a part of the Oregon State College Agricultural Economics Survey indicated a strong dissatisfaction by the water users toward the present operation of the irrigation project. A complete summary of the results of this questionnaire is included in Appendix XI-C. These comments emphasize the inadequate condition of the project, and the desire of the residents to irrigate more extensively than now permissible by present facilities. Some of the more frequently made comments submitted by water users regarding the project facilities and its management are:

A. Desire additional land leveling.
B. Land leveling has been poorly done. Costs are high.
C. Have difficulty in irrigating land.
D. Water quantity is inadequate.
E. Cannot irrigate as often as desired.
F. Water is not delivered in sufficient heads.
G. Ditches and structures are poorly maintained.
H. Need for additional irrigation facilities.
I. Desire more information on irrigation methods.
J. Desire information on use of sprinkler systems.
K. Irrigation water service should be improved.
L. Poor engineering throughout project.
M. Lack of interest by Agency Land Operation personnel.

11-5.17 Operating Budget. The $3,130.00 tentatively allocated to the project for FY 1960 and 1961 will not be sufficient if the pro rata share of Land Operations overhead is deducted. The length of the delivery system which requires more than average maintenance in some locations, the number of structures needed, and the small number of water users on each unit are some of the reasons the project requires allocation of funds in excess of collections to operate and maintain itself. The assessable lands are now being charged $2.00 per acre annually, an amount that is unreasonably small. Total billing made each year for the project at $2.00 per acre amounts to $2,570.50. This is less than the amount needed to operate and maintain the project properly from year to year. If the project were to remain in its present status, the average per acre operation and maintenance assessment based on actual operating costs should be raised to approximately $6.00 per acre. See paragraph 11-5.19.

11-5.18 The preliminary budget estimate FY 1960, 1961 for the project is tabulated:

Table 11-5.18A Preliminary Budget, FY 1960, 1961.

Cost Code	Cost Account Description		
815.1	Operation.	$ 2,300	$ 2,500
815.2	Maintenance.	2,300	2,500
849.1	Adm. and eng. salaries.	2,174	2,431
	Total O and M.	$ 6,774	$ 7,431
	Deduct amount financed from assessments (800 funds).	574	574
	Net appropriation required.	$ 6,200	$ 6,857

11-5.19 Estimated annual operation and maintenance charges for each of the units is reported (56, pp. 30-31). The total project annual expense is estimated to average $7,540.00. The average operation and maintenance charge for the project based on this estimate is $5.86 per acre. See note 1/

Table 11-5.19A Estimated Annual O & M Costs

Mill Creek Unit

Diversions and headgates	$ 270.00
Turnouts	120.00
Canal cleaning	1,000.00
Ditch cleaning	1,000.00
Ditch rider	900.00
Total	$3,290.00

3,290.00/841.93 = $3.91 per acre 1/

Simnasho Unit

Structures	$ 15.00
Ditching	30.00
Ditch rider	160.00
Total	$ 205.00

205.00/39.96 = $5.13 per acre

Shitike Unit

Structures	$ 40.00
Diversion maintenance	30.00
Ditching	520.00
Ditch rider	260.00
Total	$ 850.00

850.00/70.17 = $12.11 per acre 1/

Tenino Unit

Structures	$ 100.00
Ditching	30.00
Ditch rider	200.00
Total	$ 330.00

330.00/37.97 = $8.69 per acre 1/

Middle Warm Springs Unit

Diversion and structures	$ 850.00
Canal maintenance	850.00
Lateral maintenance	100.00
Ditch rider	400.00
Total	$2,200.00

2,200.00/206.20 = $10.67 per acre 1/

Lower Warm Springs Unit

Diversion	$ 100.00
Ditch maintenance	250.00
Structures	15.00
Ditch rider	300.00
Total	$ 665.00

665.00/90 = $7.39 per acre 1/

11-5.20 Reimbursible Funds. The small annual appropriations continuing from year to year coupled with the initial amounts allocated for investigations, surveys, and construction have increased the total reimbursible funds due as liens against the project lands to nearly $300,000.00. The average lien of nearly $230.00 per acre is beyond the capability of the land for repayment under present farming patterns on the reservation. The lien increases yearly, with nearly one-half of the assessed lands now receiving no irrigation service.

Section 11-6: Rehabilitation of Existing System.

11-6.1 Resolution #969 and #1210. By action of Resolution #969, dated June 6, 1955, it was deemed desirable by the Tribal Council that further Operation and Maintenance charges against the project be stopped, and that as of January 1, 1956 the Confederated Tribes take over responsibility for operation and maintenance of the entire project. Because the project had not been successful, or greatly beneficial to the residents, and because the Tribes agreed to assume full responsibility for the operation and maintenance of the project in the future, it was requested that all accumulated construction, operation, and maintenance charges be cancelled.

11-6.2 By resolution #1210, dated January 24, 1957, the request of Resolution #969 whereby operation and maintenance of the projects be turned over to the Tribes was rescinded. The request was made that the Bureau of Indian Affairs take such steps as may be necessary to develop the existing facilities for the purpose of bringing about the economic independence of the residents.

1/ Unit O and M costs revised from report (56, pp. 30-31) to be consistent with reported acreages and total costs.

11-6.3 Economic and Feasibility Report, 1958. An economic and feasibility investigation of the existing irrigation facilities and their utilization was prepared and submitted by Stimpson (56) in 1958. A summary of this report appears in paragraph 11-5.5. The recommendations relative to each of the six existing units was the same, being:

A. Cancellation of all construction charges.

B. Cancellation of operation and maintenance charges (R800).

C. Cancellation of all accrued and unpaid operation and maintenance assessments.

D. Turn each unit over to the water users of the Tribes.

E. The Tribes assume the responsibility for management, operation and maintenance of all units.

11-6.4 Resolution #1521. By Resolution #1521, dated May 24, 1958, the Tribal Council resolved that the Tribes assume the responsibility for management, operation and maintenance of all units on the reservation in the interest of the water user, and if deemed necessary to assure proper irrigation development on the reservation, making necessary assessments against lands benefited to defray costs. It was requested that the Congress of the United States take such action as is necessary to cancel all outstanding loans, and unpaid operation and maintenance assessments due the government as a result of the irrigation program on the reservation. The request was made that all charges and unpaid assessments accruing against the project up to and including the date of final action also be cancelled.

11-6.5 Rehabilitation Estimate. Personnel of the Agency Land Operations Office prepared an estimate (56, p. 32) of the funds required to rehabilitate the project to meet satisfactory standards or performance prior to turning it over to the Tribe, as requested in Resolution #1521. The estimate is for completing improvement of the project to standards adequate to deliver sufficient water on demand to all the lands under present assessment:

Table 11-6.5A Rehabilitation Estimate

Mill Creek Unit

Earthwork around diversion	$ 250.00
Minor diversions (replacement)	1,200.00
Four turnouts (replacement)	600.00
Re-work four miles main canal	4,000.00
Ditchwork (20 miles lateral)	1,000.00
Total	$7,050.00

7,050.00/841.93 = $8.37 per acre

Simnasho Unit

Channel cleaning and drop structures, 1/	$4,200.00
Total	$4,200.00

4,200.00/39.96 = $105.11 per acre

Middle Warm Springs Unit

One check and turnout	$ 500.00
Rebuild 600' main canal	500.00
Total	$1,000.00

1,000.00/206.20 = $4.85 per acre

Lower Warm Springs Unit

Rebuild 2,640' main canal	$2,000.00
Total	$2,000.00

2,000.00/90.00 = $22.22 per acre

Tenino Unit 1/

One diversion structure	$ 400.00
Three checks	350.00
Total	$ 750.00

750.00/37.97 = $19.75 per acre

1/ Not sufficient water available for irrigation during the entire season of use.

Shitike Unit 2/

Complete installation of headgate (Headgate is at the site: Need to be placed and backfilled)	$ 100.00
Check and wasteway	500.00

2/ It is assumed that the O&M cost allowed for ditch maintenance is high enough to make rebuilding this main canal unnecessary.

Total	$ 600.00

600.00/70.17 = $8.55 per acre

TOTAL FOR ALL UNITS	$15,600.00

1/ In original report (56, p. 32) no funds allotted for Simnasho Unit. $4,200.00 designated for rehabilitation in revised estimate by Bureau of Indian Affairs. (Letter, A.W. Galbraith, August 1960)

Replacement Equipment

Pick-up	$1,600.00	
Putting Equipment in good condition	800.00	1/
Minor tools	1,400.00	
Total	$3,800.00	2/
TOTAL PROJECT REHABILITATION COSTS	$19,400.00	
AVERAGE REHABILITATION COSTS 19,400/1286.23	$15.08 per acre	

11-6.6 The estimate of 1958, paragraph 11-6.5, may be less than that actually required to improve the project to satisfactory standards. The Bureau of Indian Affairs suggest a 10% contingency be added to the total estimate of $19,400.00 to cover increased cost of labor and materials since the estimate was prepared in 1958. It is difficult to predict the actual cost required to process the rehabilitation program.

11-6.7 The estimated rehabilitation costs for the Simnasho Unit appears to be excessive when compared with estimated costs of other units. If the assessed acreage of this unit is to remain at the existing 40 acres, the justification of expenditure of $4,200.00 for this small unit is questioned. The combined expenditure of only $1,600.00 for both the Shitike and Middle Warm Spring units does not seem sufficient in view of this size of these units and the high annual operation and maintenance expenditures necessary resulting from weak canal systems. The statement for justification of the low rehabilitation cost at the Shitike Unit, see Table 11-6.5A, "It is assumed that the O&M cost allowed for ditch maintenance is high enough to make rebuilding this main canal unnecessary", does not appear to be sound. The standards of the rehabilitation should be independent of any budgeted funds to operate the system, but should be based on the economic balance between rehabilitation expenditure and the reduction of maintenance costs. These two systems will not be improved to adequate standards of performance until the canal systems have protection from hill-side erosion and seepage.

11-6.8 Operation of Rehabilitated Project. The possibility of further irrigation development on the reservation depends greatly upon the success of the present project. Continued development or further growth of irrigation facilities is dependent upon the successful use of facilities already constructed. The rehabilitation of the existing project represents the most economic choice for an immediate increase in irrigation facilities on the reservation. The location of the present units have used those sites where irrigation can be developed on the reservation for relatively small initial costs. All new development must of necessity be of a more complex type in operation and have higher initial expenditure.

1/ $5000.00 for dragline repair of report (56,p.33) deleted in revision by Bureau of Indian Affairs. $800.00 for general equipment repair added in revision.

2/ Reported as $3,200.00 in revised estimate of rehabilitation program by Bureau of Indian Affairs. (Letter, A.W. Galbraith, August, 1960)

11-6.9 Many factors have contributed to the general poor performance of the project during the past twenty years. It is impossible to single out any one major cause. Undoubtedly the project has not been managed during the past twenty years in a manner to create great interest by the residents. The fact that during the first three years, 1935 to 1938, a succession of three different men assumed responsibility for design and construction of the project was not conducive to efficient progress. It is difficult to attract trained operating and engineering personnel to small irrigation projects. It appears today that there is genuine interest by the residents in obtaining better use of irrigation facilities. The rehabilitation of the present system to acceptable standards and its successful operation and use is basic to all further irrigation on the reservation.

11-6.10 The successful use of the project will require qualified personnel to direct its operation. The mere transfer of responsibility of management from the Bureau of Indian Affairs to the Tribes will solve nothing, for efficient operation and sound management policy is required in any event. The small size of the existing project can not justify an engineer employed full time, nor is it necessary. However, all operation, maintenance, and construction performed by operating personnel should be under the direct supervision of a qualified engineer. To allow the rehabilitated project to function otherwise would be a most unfortunate event to the water users dependent upon its operation. The duties and responsibilities of an engineer for the rehabilitated project should be:

A. He should determine water supply and requirements of the project. An accurate and continuing inventory of the disposition of water throughout the project is invaluable to assure adequate performance of existing facilities, and to provide realistic planning for future expansion.

B. He should be responsible for designing and construction of all structures essential to storage, diversion, conveyance, delivery and distribution of water. It is important that all structures by substantially and economically built so that they may be relied upon during the critical irrigation season.

C. He should have direct responsibility and establish all maintenance programs of the project. This means acquiring the necessary equipment to perform the job, and establishing a systematic program of preventive maintenance that assures continued operation of the project at a minimum of charges to the water user.

D. He should establish or advise administrative policy at the project.

E. He should be available to the water users to furnish assistance or guidance on irrigation methods. This is an area of responsibility that appears to have been neglected on the reservation, and is of utmost importance.

F. He should be available to the water users for all engineering required in land leveling operations or other soil preparation procedures.

Section 11-7: Irrigation Methods

11-7.1 Methods of Field Distribution. Irrigation water is applied to land by four general methods, being applied either by (a) corrugations or furrows, (b) flooding of the surface, (c) sub-irrigation where the surface is wetted little, if any, and (d) overhead sprinkler systems. The advantages of each depend upon soil, characteristics, topography, availability of water, cropping practices, and amount of labor required to control the water. On the reservation, each general type of irrigation method can be advantageously used.

11-7.2 Corrugations or Furrows. Corrugations or furrows are of two main types, (a) large deep furrows, eight to ten inches deep, for such cultivated crops as potatoes, and for orchards, and (b) small corrugations, three to five inches deep, for grains or forage crops. Although row crops are customarily irrigated by furrows or corrugations, other methods are equally if not sometimes more satisfactory. The length of the furrow or corrugation depends upon the slope of the land, soil texture, condition of furrow, and availability of water. Lengths of 300 to 600 feet generally give best performance. Excessive deep percolation losses and soil erosion near the upper end of the field result from use of long furrows. The majority of furrow irrigation problems are associated with excessively long furrows. Some advantages of furrows are (a) reduced evaporation losses, (b) lessening of puddling in the heavier soils, (c) ability to cultivate sooner after irrigation, (d) adaptability to a wide variation in ground slope, (e) generally low land leveling costs, and (f) ability to utilize relatively small heads of water. Some disadvantages of the furrows are (a) uneven application rates between upper and lower end of furrows unless irrigator is careful, (b) and tendency for the smaller furrows or corrugations to become clogged with debris.

11-7.3 The ability to use furrows on land having a wide variation in slope has particular application on the reservation where the shallow soils create land leveling problems. Although the present condition of the irrigation system on the reservation generally prevents the delivery of adequate heads of water for flood irrigation methods, this factor should be considered as a temporary condition only, and attention be given to improving the system.

11-7.4 Flooding. Irrigation by flooding is of four types, (a) ordinary flooding from field ditches, (b) borders, (c) checks, and (d) basins. While corrugations or furrows apply water directly to only one-fifth to one-half of the ground surface, the flooding methods inundate for a short time the entire irrigated area.

11-7.5 Where water is applied to irrigated lands directly from field ditches without any levees or borders to guide its flow, or to otherwise restrict or control movement, the irrigation is termed ordinary flooding from field ditches. There are variations of field ditch flooding, one of the more common being flooding from ditches located on contours. Advantages of this method are the low initial cost of land preparation and the possibility for irrigation of lands too irregular for other flooding methods. This method is particularly applicable in places where water is abundant and inexpensive. Disadvantages of ordinary field ditch flooding are associated with poor irrigating efficiencies. Ordinary flooding from field ditches have application on the reservation for irrigation of forage crops on lands not suited for leveling. Because direct flooding usually results in great loss of water by surface runoff and deep percolation, and because the existing and potential irrigation systems on the reservation are generally of a diversion type having little, if any, storage, the use of such a wasteful method should be restricted to times not conflicting with more efficient methods. That is, field moisture of marginal forage lands could be increased during the early and late part of the summer, before and after water demand from the more valuable crops occurs, and when non-diverted water would otherwise continue to flow unused in its natural channels.

11-7.6 Dividing an irrigated tract into strips generally 30 to 70 feet wide and 350 to 1200 feet long, separated by low earth border levees, is called the border-strip method. The surface must be nearly level in cross section across the levees, so that a sheet of advancing water from the upper end of the strip covers the entire width. It is desirable that the gradient be constant throughout the length. Land leveling requirements are more critical with the border strip method than with the furrow flooding. Currie, Wolfe and Swarner (9, p. 10) report a more efficient use of water by the border method than by furrows on the North Unit, Deschutes Irrigation Project. The satisfactory use of the border method requires heads of about one cubic feet per second to be turned into each 30 foot wide basin. The lands on the reservation that are favorable for border flooding are at the flatter and deeper soils that permit the required leveling. The general high initial cost of preparing uneven land for the border method limits its use on the reservation.

11-7.7 Irrigation by check flooding requires running comparatively large heads into relatively level plots surrounded by levees. Checks are sometimes made by building small contour levees at three or four inch vertical intervals and connecting them with cross levees. The check flooding is advantageous for irrigation of forage crops or cereals. Generally large irrigating heads are desired. In general, the checks should not be greater than two acres, with checks as small as one-half an acre suggested for steeper slopes. Advantages of contour checks are (a) less leveling is required than for furrows, border-strips, or a rectangular system of checks, (b) large heads of water can be used, (c) less irrigation labor is used, and (d) small amount of ground preparation in constructing checks. Disadvantages are poor water efficiencies, particularly at the larger sized checks. Contour checks may be thought of as a refinement of field ditch flooding, and has wide application on the reservation.

11-7.8 The use of basin flooding requires the construction of flat rectangular tracts surrounded by levees. The flooding of basins is a common method of irrigation of orchards, and does not appear to have general application in the uneven terrain or farming patterns of the reservation.

11-7.9 Sub-irrigation. Applying water so that horizontal subsurface percolation occurs is called sub-irrigation. In a few localities of the reservation the natural soil and topographic conditions are favorable for sub-irrigation. The general requirements are an impermeable subsoil at depths of six feet or more, a highly permeable loam or sandy loam surface soil, and generally uniform topographic conditions having moderate slopes. Two general methods of subirrigation are: The controlled seepage from lateral supply ditches, and a general uncontrolled seepage by excess application of water to higher lands. Artificial sub-irrigation by applying water from buried pipes directly to the soil is generally not economically practical at the reservation. The advantages of sub-irrigation are low labor cost, low cost of land preparation, and non-interruption of field work. Excess waterlogging and alkali accumulation can occur as a result of improper sub-irrigation. Soils permitting reasonable success by sub-irrigation on the reservation probably occur on the sloping valley floors of such streams as Tenino Creek, Shitike Creek, or on the deeper soils of Schoolie Flat underlain with impermeable lenses.

11-7.10 Overhead Sprinklers. Since the early 1940's the use of sprinklers for distribution of irrigation water has greatly increased. Portable units are being used more extensively than those designed for a permanent location. The portable low-angle systems consist of a portable or semi-permanent main line, portable lateral pipe lines and sprinklers, and a portable or semi-permanent pumping plant. Systems are also classified according to the magnitude of operating pressure. The lower pressure systems have lower initial cost and lower pumping costs. Advantages of higher pressures are claimed to be lower labor cost in moving laterals.

11-7.11 The results from the misuse of sprinkler equipment can be extremely disappointing. The important factors to the success of this type irrigation are the correct design of a system having units of good manufacture, and the efficient operation of the designed system. There are four basic engineering considerations in the design and operation of sprinkler equipment, the (a) water supply, (b) climate, (c) crop to be irrigated, and (d) soil and topography. The information of water supply concerns the quantity of water available, location of water source, and delivery schedule. Factors of climate which control sprinkling practice are temperatures, natural precipitation, and wind velocities. Root zone depth, and consumptive water use by the crop to be grown effect both design and operation of a successful system.

Required information of the soil is soil type, depth, texture, permeability, field moisture capacity, and topography.

11-7.12 The initial cost for a sprinkler system, including sprinklers, pipe, pump and motor, is approximately $100.00 to $150.00 per acre. Generally, initial costs per acre for the larger systems are less than those of smaller acreages. With reasonable care sprinkler pipe can be expected to have a useful life of fifteen to twenty years. Little is to be gained, nor is it advisable, for a user untrained in the engineering required of system design to attempt the design of his own system. The usual result of such a venture is a poorly designed system often greater in initial cost and giving unsatisfactory performance. The operational costs of sprinkler systems are those for moving pipe settings, and power costs. While electric powered pumps are advisable, they are not necessary for satisfactory operation. A frequent criticism of sprinkler systems is the high total irrigating costs. Whether sprinklers are the best choice of applying water depends on some of the factors outlined below.

11-7.13 The use of sprinkler systems appears to have considerable application on the reservation. That there is today interest in sprinkler irrigation by the residents is evident by the numerous comments during the agricultural economic survey conducted during the summer of 1960 by Oregon State College. See Appendix XI-C. Factors to consider in selection of sprinkler irrigation on the reservation are:

A. Sprinklers are ideally suited to applying light amounts of water to the shallow soils of the reservation. Where the shallow soils having low field moisture capacity exist, the ability to apply water in frequent and light applications is of great importance.

B. Irrigation efficiency of sprinkler systems is usually good. At places on the reservation where water is in short supply, sprinklers offer a means of efficient water placement.

C. Sprinkler irrigation permits a resident having a source of surface water nearby to immediately begin an irrigation program with little, if any, additional land preparation. The initial fixed cost of open channel construction is eliminated.

D. One of the major advantages of sprinkler systems on the reservation is the elimination of land leveling. The shallow soils require great care in land leveling design. Where the shallow soils occur on uneven terrain, the required leveling permitting gravity irrigation is often prohibitive.

E. Sprinkler irrigation can allow lands on the reservation to receive supplemental water that is physically unavailable by other means. These are the many scattered small tracts of irrigable lands too small and remote to justify gravity systems, the tracts near existing systems that could be productive if supplied with water but lie outside the area commanded by the ditch, and uneven lands that cannot satisfactorily be irrigated by gravity flooding.

F. Sprinkler irrigation may conform better to the social patterns of the residents. It is not the intent of this discussion to imply that the satisfactory operation of a sprinkler system does not require discipline from the operator. However, a good system can be operated on a generally routine schedule, not requiring the continual adjustments of water control necessary in gravity surface systems. Continual attendance is not necessary, a fact that may contribute to increased use of irrigation on the reservation.

11-7.14 Water Requirements. No accurate measurements are available of the water requirements of the project. The use of water appears to have been less than that to be expected for an irrigation project normally having an abundance of water at the diversion into the main canal. Any apparent sub-normal use of water in the past, or during the present, is attributed to restricted capacity of the system due to either design or maintenance, or to the voluntary partial use by the water user of facilities available. Either cause is temporary and should not be construed to be a factor in consideration of future irrigation development on the reservation.

11-7.15 Irrigation efficiencies have undoubtedly been very low on all units of the reservation. Many factors contribute to these low efficiencies, some being (a) insufficient irrigating heads, (b) poor land leveling and soil preparation, (c) ill-advised irrigation methods, (d) excessively long runs or large checks, (e) shallow soils, (f) permeable soils, and (g) inattendance of irrigator.

11-7.16 Irrigation water requirements on the reservation are assumed to approximate those now being experienced on the North Unit, Deschutes Project. Project seasonal application was initially about 2.4 acre-feet per acre, but has now increased to approximately 3.2 or 3.4 acre-feet per acre. On future developments on the reservation, where an agricultural economy will be somewhat diversified but mainly directed toward forage crops, a design requirement of 3.4 acre-feet per unit acre is assumed.

11-7.17 Irrigation Applications. To maintain reasonable irrigation efficiencies on the shallow soils of the reservation frequent and light applications are required. The available water holding capacity of the soils of the reservation, or the amount of water required to raise the soil moisture content from the wilting point to saturation is probably around one inch per foot of soil depth. At a 50% irrigating efficiency this will require approximately seven or eight irrigations per season to apply 3.4 feet of water to the reservation soils averaging about three feet of root zone. Israelson (25, p. 206) lists available field capacities in inches of water per foot of soil.

Table 11-7.17A Soil Moisture Field Capacities

Soil Type	Field Capacity	Before Irrigation	Available Field Capacity
	Inches water per foot of soil		
Sandy loam	3.3	2.1	1.1
Clay loam	3.9	3.0	0.9
Gravely loam	3.0	1.9	1.1

Section 11-8: Land Leveling

11-8.1 Design factors at the Reservation. Two problems of primary concern regarding land leveling on the reservation are those of preservation of top soil, and establishment of satisfactory gradients. Some of the problems that have been associated with land leveling do not appear to be entirely those of leveling design and construction, but are traceable to inadequate water delivery. The need for improved land leveling on the reservation is recognized by the water users. See Appendix XI-C.

11-8.2 Preservation of Top Soil. Uneven terrain of unleveled lands, often accompanied by shallow top soil, requires cautious design of land leveling on the reservation. Because much of the land covered by existing or future irrigation project is found to have generally shallow top soils, leveling if not carefully done will expose sterile soil. Under adverse conditions, the leveled tract at both areas of cut and fill may be forever exposed by a material capable of supporting growth of nothing but noxious weeds.

11-8.3 In such cases it is best to use an irrigation method that enables coverage without leveling. Where this is not possible, the minimum amount of leveling that will permit water spreading is advisable. Such lands are usually better cropped by forage, which allows considerable diversity of irrigation practice. If considerable excavation is absolutely necessary to the cropping practice desired, the stock piling of the top soil and its later redistribution may be the only solution. Earth stock piled for subsequent transfer must be judiciously located, and in magnitude be kept to a minimum as it requires double excavation costs. At no time is leveling recommended for the lands of the reservation without investigation and provision for retaining adequate soil covering.

11-8.4 Gradient. The problems of gradient for leveled lands are closely associated with those of irrigation methods, cropping practices, and soil texture. Water users on the reservation that now experience difficulty in forcing water across their leveled fields tend to direct all their trouble toward improper leveling. While in many cases this may be true, it appears that a more reasonable cause of this trouble is the use of insufficient irrigating heads. Excessively large checks, borders, or long furrows in the permeable surface soils increase irrigation problems where small irrigating heads are used.

11-8.5 The importance of erosion control in establishing gradients for land leveling is stressed. Water losses due to excess percolation as a result of low application rates or flat gradients are less serious on most of the irrigable lands of the reservation than soil loss due to large rates of application on excessive slopes.

11-8.6 Costs. Unit excavation costs for land leveling as charged by commercial operators are normally between 15 to 30 cents per cubic yard. The earth moving costs for leveling on the reservation by Bureau of Indian Affairs equipment are reported by the Agency Land Operations as being approximately 15 cents per cubic yard. Using these figures as a sole criteria, the charges for land leveling as performed by the Agency equipment are reasonable. The total land leveling charges per acre of irrigable lands is subject to wide variation, both in the total charges required, and in the total charges justified. Total charges to level an acre of ground at the unit prices quoted above can be as little as $10 to well over $100. The amount of money required for leveling depends upon the degree of refinement required in the leveling.

11-8.7 Land Leveling Suggestions. The following suggestions for land leveling requirements are offered for lands on the reservation:

A. Prior to design of leveling, a complete soil and topographic survey should be made of the tract. For the mechanics of design of leveling operation and the irrigation methods to be used, special emphasis should be placed on topography, soil texture, soil depth, and sub-surface geology.

B. Irrigation methods to be used should be a factor in determining finished land gradients. Where lands have a great uneveness of terrain, the selection of irrigation method is severely restricted. Complete understanding between the engineering personnel and water user is required to assure proper design and use of the completed tract.

C. While minimizing quantity of excavation always has importance from a standpoint of economy, it has particular urgency at the shallow soils of the reservation. To eliminate sterile sub-soil outcrops or inadequate top soil covering, gradient design must be carefully determined, provision made for secondary top-soil storage if needed, and detailed excavation to embankment schedules prepared to assure optimum soil placement.

D. Adequate field supervision must be available to assure the job is constructed as designed. This requires clearly marked field stakes in sufficient numbers to provide no opportunity for uncertainty by equipment operators. If haul schedules are prepared they should be clearly understood by operator and followed during construction.

Section 11-9: Potential Irrigation Development by Geographic Area.

11-9.1 Log Springs. Approximately 250 acres in the Log Springs area are mapped in the recent soil survey by the Bureau of Indian Affairs to be of a classification considered irrigable. However, the difficulty of obtaining water to serve this area makes the feasibility of irrigation doubtful. Only one other reference in previously prepared reports has ever made mention of possible irrigation of this region. This is the report of 1941 (73, p. 38). No suggestion was made as to the method of obtaining water.

11-9.2 The only available source of stream runoff in this area is from Coyote Creek, it being intermittent and not adequate to serve irrigation. It is possible that small drainageway storage could be constructed that would hold enough water to apply one or two light irrigation applications to small fields. The soil in this region is quite tight and impermeable. Small dams could be expected to hold water quite well. There are several places where small dams could be constructed that have the watershed sufficient to fill reservoirs having capacity of 25 to 50 acre-feet. A small dam properly constructed could hold water into the early summer and allow a couple of light irrigation applications to fields of 20 to 30 acres. The construction of such dams should be preceeded by adequate runoff and permeability studies to assure the satisfactory operation of the small irrigation enterprise.

11-9.3 The Island. The Island can be irrigated by diversion from the upper Warm Springs River. A plan for supplying irrigation water to the Island is presented in section 11-13. This plan is a coordinated plan for supplying water to the Island, Schoolie Flat, and Simnasho valley. Water diverted from the Warm Springs River near the lower end of Schoolie Pasture would be used to supply water to a canal that enters the north end of the Island. The irrigation of the Island appears to be dependent upon the adoption of a plan similar to that of section 11-13. The relatively small amount of irrigable acreage found on the Island does not appear to justify construction of a diversion canal to serve the Island only.

11-9.4 The location of an unregulated diversion from Warm Springs River to serve only the Island would require a main canal having a minimum length of approximately fourteen miles. If Schoolie Flat were to be served by a canal not traversing the Island, such as outlined in section 11-14, the entire cost of a main canal of fourteen miles length to serve the Island would be chargeable to the development of the 650 acres on the Island. Assuming overall construction cost of the canal at $3.00 per linear foot, and unit lateral development costs as $125.00 per acre (see 11-13.27) the per acre cost of an independent Island development would be approximately $465.00 per acre. The plan is not feasible.

11-9.5 A plan for supplying irrigation water to Schoolie Flat, Miller Flat, Sidwalder Flat and Dry Creek from a power canal serving the Miller Flat Power site (see paragraph 12-5.9) is presented in section 11-14. Although the estimated pro-rated cost for construction of irrigation facilities is more favorable than an irrigation development bringing water to Schoolie Flat by a canal traversing the Island, the conflict of interest for the limited supply of water does not appear to favor a joint power-irrigation program. For this reason it appears that the most reasonable method of irrigating the Island is from a canal serving irrigation demand only, diverting water from the Warm Springs River in the plan outlined in section 11-13.

11-9.6 Schoolie Flat. There are two methods by which irrigation water can be brought to Schoolie Flat, each requiring diversion from Warm Springs River at the outlet of Schoolie Pasture. An irrigation development of Schoolie Flat would constitute nearly 60% of the total potentially irrigable acreage on the reservation.

11-9.7 One method for irrigation of Schoolie Flat is described in section 11-13. The plan would require regulation of Warm Springs River by diversion from a reservoir having a capacity of approximately 30,000 acre feet. Diversion from the north side of the river would enter the north edge of the Island, traverse the north half of the Island, and cross Beaver Creek by a siphon west of the north edge of Schoolie Flat. A diversion from the siphon inlet would provide irrigation water to the Island. Water on Schoolie Flat would continue to flow by gravity to discharge into a pumping forebay at the north edge of the Flat and about one-quarter mile east of the Simnasho road. Gravity water could be diverted down natural channels into Quartz Creek where it would serve the Simnasho unit. Water to irrigate Schoolie Flat would require the installation of a pumping plant. The entire development is estimated to cost approximately two and one-third million dollars, and has a unit acreage cost for the 5,870 acres in the combined areas of Schoolie Flat, the Island, and Simnasho of $403.00 per acre.

11-9.8 The alternative to the method described in paragraph 11-9.7 is a coordinated development with hydro-electric development, and described in section 11-14. The hydro-electric development is described in Helland's (19) report and in paragraph 12-5.3. The hydro-electric development would require the construction of 100,000 acre-feet of storage at Schoolie Pasture, a power canal traversing Sidwalder Flat and Miller Flat. The inlet to a low pressure conduit would be located on Miller Flat near the upper drainage to Dry Creek. A power site located on the Warm Springs River would be about five and one-half miles upstream from Indian Head Canyon. See Appendix XII-F of Helland's (19) report. The power canal could provide irrigation water by gravity to lands on Sidwalder Flat not covered by diversion from Mill Creek Flat (see paragraph 11-9.12), to Miller Flat, and to Dry Creek. Discharge from the penstock at the Miller Flat power station could supply water to a pressure conduit located on the north face of the Warm Springs canyon, supplying water by gravity to an elevation on Schoolie Flat of about 2,500 feet above sea level. Pumps at the conduit outlet would pump water to a maximum elevation of 2,800 feet above sea level, and would provide coverage of 5,010 acres on Schoolie Flat. Waste water at the north end of Schoolie Flat would be available for irrigation to Simnasho valley. A total of 7,017 acres would be served by this system. The Island would not be served from this unit. The total estimated pro-rated construction cost chargeable to irrigation, and allowing simultaneous operation of both power and irrigation facilities, is slightly over four million dollars. The per acre development cost for the 7,017 acres of irrigated land is $549.00 per acre. For non-simultaneous operation the estimated pro-rated irrigation development cost is about two and one-half million dollars, or about $353.00 per acre. The pro-rated costs chargeable to irrigation are based on proportionate canal capacity and proportionate water consumption of irrigation demand.

11-9.9 Although the non-simultaneous operation of the joint development by power and irrigation provides the lowest estimated cost for irrigation development to Schoolie Flat, it is doubtful that the limited amount of water available to power after irrigation demand is satisfied would be sufficient to be attractive to power. However, because of the seemingly advantage to irrigation by construction of a joint development, this possibility should be more fully explored.

11-9.10 Miller Flat. The irrigation of Miller Flat appears to be dependent upon the construction of a power canal traversing these lands. See paragraph 12-5.9. The Flat contains only 485 acres of mapped lands of Class I, II, and III. See Appendix XI-D.1. These potentially irrigable lands are widely scattered within class VII tracts. A discussion of the estimated costs chargeable to irrigation of a joint power-irrigation development to serve Miller Flat is discussed in section 11-14. The plan for non-simultaneous operation, see paragraph 11-14.12, is favorable from an irrigation consideration, but conflict of interest of limited supply of water does not appear attractive to power utilization. A plan for simultaneous operation, see paragraph 11-14.9, is not feasible due to excessive pro-rated irrigation costs.

11-9.11 Water from Mill Creek appears to be better used for an expansion of the existing Mill Creek unit at Sidwalder Flat. As available supply from Mill Creek is inadequate for a complete development of Sidwalder Flat, water from this source would not be available for Miller Flat. If the hydro-electric potential of the Warm Springs River were developed as described in Chapter XII a power canal would traverse Miller Flat, thereby providing water for irrigation. The irrigation potential of Miller Flat and Dry Creek does not appear sufficient to justify a hydraulic system designed to serve irrigation only.

11-9.12 Sidwalder Flat. Irrigation of Sidwalder Flat is most economically available from water from Mill Creek. The recent soil survey of the Bureau of Indian Affairs mapped 2,069.5 acres of land classified as I, II, and III on Sidwalder Flat. See Appendix XI-D.1. Three methods of irrigation for Sidwalder Flat are possible. The first is from unregulated diversion from Mill Creek. This is discussed in section 11-10. Computations based on the meager available records of discharge from Mill Creek indicate that 1,079 acres could be irrigated. The second method of irrigation is from regulated diversion of Mill Creek. Irrigation by regulated diversion is described in section 11-11. It is estimated that the water supply from regulated diversion is sufficient to irrigate 1,586 acres. The third method of supplying irrigating water to Sidwalder Flat is from diversion from Warm Springs River. This diversion, either from a power canal or from a canal constructed solely for irrigation demand, could supply water to lands on Sidwalder Flat, Miller Flat, and Dry Creek Valley. The diversion, if supplying water for power, could also furnish water to Schoolie Flat. See paragraph 12-5.9.

11-9.13 Diversion from a regulated Mill Creek, is clearly the most favorable of the Mill Creek developments. The estimated per acre cost of development, less than $170.00 per acre, is the least costly of any potential irrigation development on the reservation. Irrigation by diversion from an irrigation main canal receiving water from Warm Springs River, located in general at the location of the Miller Flat power canal shown in Appendix XII-F would serve an additional acreage of 1,798 acres. The canal would allow irrigation on the 484 acres on Sidwalder Flat not covered by the plan of section 11-11, 485 acres on Miller Flat, and 829 acres in Dry Creek Valley. The construction of 25 miles of main canal would be required. See paragraph 11-14.8. The construction of this length of canal to bring into irrigation such a limited amount of irrigable lands does not appear justified. The feasibility of construction of a power canal supplying water for irrigation to these areas is discussed in section 11-14.

11-9.14 The conclusion is made that irrigation by regulated diversion from Mill Creek is the most feasible method of development of Sidwalder Flat. By this method, it is estimated that all but 485 acres of the potentially irrigable lands can be developed.

11-9.15 Dry Creek Valley. Dry Creek Valley contains 828.9 acres of land mapped in the recent soil survey, Appendix XI-D.1, as class I, II, or III. All are considered potentially irrigable. The only sources of water for Dry Creek are from diversion from Mill Creek or from Warm Springs River. Neither appears to be economically available, as water from Mill Creek can be most favorably used on Sidwalder Flat, and costs of bringing water from Warm Springs solely for irrigation are excessive.

11-9.16 The soils in Dry Creek Valley are alkaline. The class I, II, and III lands are widely scattered in class VII lands. The doubtful response of these soils to irrigation, high cost of lateral construction, and high cost of main canal construction are factors contributing to lack of feasible potential irrigation development at Dry Creek Valley. Construction of diversion canal from Mill Creek to supply water to Miller Flat and Dry Creek Valley would require about 12 miles of main canal construction. This diversion would require increased costs of development of Sidwalder Flat, for the only alternative supply to Sidwalder is from a markedly more costly diversion from Warm Springs River. The conclusion is that the increased overall development costs to bring into irrigation the lands on Miller Flat and Dry Creek Valley are not justified. The only feasible source of water for either Dry Creek or Miller Flat is from a power canal serving the Miller Flat power site. See paragraph 12-5.9.

11-9.17 Metolius Bench. On the Metolius Bench, 1,434.9 acres of land mapped as class I, II, and III are found. The sources of water for this area are Shitike Creek, Metolius River, and Whitewater River. The discharge of Shitike Creek is not sufficient to supply water to this area and also to the more economic irrigation units further downstream. Hence, water from Shitike Creek is not available to Metolius Bench. Pumping costs from Metolius River, even from the anticipated elevation of the Round Butte reservoir would be prohibitive. The remaining source is the Whitewater River.

11-9.18 An unregulated diversion from Whitewater River at approximately 3,600 feet above sea level near location 10/9-9N would have an abundant supply of water, and would be in a topographic position to supply water to the land on Metolius Bench and also to the combined acreage of Tenino Bench, Dry Hollow, and Seekseequa Creek. The total combined acreage of the unit, of which the Metolius Bench is a part, is shown by the following table:

Table 11-9.18A Irrigation from Whitewater River Acres. 1/

Area	Class I	Class II	Class III	Other
Metolius Bench	5.7	795.3	633.9	7,677.6
Tenino Bench	---	---	232.7	168.1
Dry Hollow	0.8	447.8	592.1	1,323.3
Seekseequa Creek	---	68.1	106.5	346.1
TOTAL	6.5	1,311.2	1,565.2	

Total of class I, II, III: 2,882.9 acres

1/ From soil survey by Bureau of Indian Affairs, Appendix XI-D.1.

11-9.19 The main canal, located on the north bank of the river would traverse extremely difficult terrain for the first eight miles. At the approximate location 10/10-16N the canal would branch, the southern portion continuing for an additional 10 miles to the irrigable acreage on the Metolius Bench, the northern portion traversing along the east edge of Middle Butte and Twin Buttes to irrigate Tenino Bench, Seekseequa Valley and Dry Hollow. The northern branch of the main canal would be approximately 17 miles in length. The anticipated cost of construction of the main canal as it traverses the first eight miles along the north canyon wall of Whitewater River would likely be so great that the entire project would be rendered unfeasible.

11-9.20 The use of irrigation diversion from a power canal at the Tunnel site is discussed in paragraph 12-5.12. The conflict in use of water presents an economical limitation that would appear to prevent the use of such water for irrigation, each acre-foot of water diverted from the power penstock would mean a sacrifice of approximately three dollars to power generation. The high anticipated canal losses from canals located on the Metolius Bench would likely cause low irrigation efficiencies and excessive water consumption. The conclusion is that irrigation alone cannot bear the cost of the diversion construction, and that water at the penstock inlet to the Tunnel power site can be more profitably used for power generation.

<u>11-9.21</u> <u>Tenino Bench and Dry Hollow.</u> 1,273 acres of lands classified as I, II, and III exist on Tenino Bench and Dry Hollow. Water diverted from Shitike Creek to these lands would be in short supply, and is therefore not practical. Such unregulated diversion at approximately 3,200 feet above sea level, and at location 9/10-29C would supply a main canal along the south bank of the stream. The total length of the canal would be about fourteen miles, the first four being in extremely difficult terrain. High anticipated construction cost in this area, and the shortage of water caused by both short supply and heavy seepage losses in the main canal as it traverses the high bench lands cause the feasibility of the plan to be doubtful.

<u>11-9.22</u> The plan to use water diverted from the Whitewater River is discussed in paragraph 11-9.19. The high cost of canal construction in the first eight miles of main canal, and the unfavorable length of the north branch of the main canal to pick up the 1,428 acres at Seekseequa Creek, Tenino Bench and Dry Hollow do not appear attractive to irrigation development. Additional investigation is needed to verify this conclusion.

<u>11-9.23</u> <u>Seekseequa Creek.</u> The seventeen mile branch line serving Tenino Bench and Dry Hollow would pass to the east of Twin Butte, crossing Seekseequa Creek near its headwaters. Water diverted from the branch line into Seekseequa Creek would be available to irrigate 175 acres of land in Seekseequa Valley, 175 acres being termed class II and III in the recent soil survey.

<u>11-9.24</u> Because construction of the Whitewater diversion does not appear feasible, and because Seekseequa Creek has a minimum discharge during the summer months of one cubic foot per second or less, the only remaining opportunity for irrigation in the valley is from small reservoirs constructed near the small irrigable tracts. It would be anticipated that such small reservoirs would be subject to considerable seepage as the formation is characterized by basaltic members of the Dalles formation. The valley floor is narrow and abutted by steep canyon walls. Little opportunity exists for storage sites to catch the spring run-off from the stream. Such sites as available would permit only small capacities, sufficient only for irrigation of small tracts.

<u>11-9.25</u> <u>Deschutes Valley.</u> Approximately 250 acres of land classified as I, II, or III are found on the valley floor near the Deschutes River. These alluvial lands lie at heights above the river that do not generally permit direct diversion. Their position adjacent to the river

and their general sloping terrain suggest sprinkler irrigation. Although wells drilled into the sedimentary alluvium will generally support a sprinkler system, the valley floor is so narrow that pumping direct from the river is generally suggested. The average static pumping head for pumps installed at the river would be twenty to thirty feet. The permeable soils of moderate slopes, situated in a location protected from prevailing winds favors the use of overhead sprinkler irrigation.

11-9.26 Tenino Creek and Shitike Creek. A plan has been proposed by the Bureau of Indian Affairs for construction of an irrigation unit at the lower Tenino Creek valley and the adjacent Shitike Creek valley. The unit would consist of a gravity diversion from Shitike Creek, and a pumping plant in Tenino Creek valley. A total of 430 acres of irrigable lands would be served by the unit. The estimated cost of the unit would be less than $300.00 per acre. The plan is discussed in section 11-12. The existing 70 acres assessed in the present Shitike unit lie outside of the proposed unit.

11-9.27 Simnasho Valley. 209.5 acres of land are mapped in Simnasho Valley as being class I, II, and III. See Appendix XI-D.1. The existing water supply from Quartz Creek with the storage at the Happy Valley reservoir is inadequate for full development. Abundant water would be available to Simnasho in the event of irrigation development at Schoolie Flat. The water would be either waste run-off or spilled water from either a joint power-irrigation development or from a irrigation development. Full development of irrigation at Simnasho appears contingent upon completion of irrigation facilities for Schoolie Flat. See section 11-13.

11-9.28 Summary. A tabulation of potential irrigation on the reservation is given:

Table 11-9.28A Potential Irrigation on Reservation.

No.	Location	Reference	Acreage	Description
1.	Log Springs	11-9.1	250	No perennial stream available. Opportunity for construction of small waterway dams sufficient for irrigation of small tracts.
2.	Island	11-9.3 11-13	650	Part of 5,870 acre unit supplying Schoolie Flat, the Island, and Simnasho. Regulated diversion from Schoolie Pasture. Main canal north of Warm Springs River.

3.	Island	11-9.4	650	Unregulated diversion from Warm Springs River to serve Island only. Applicable only if plan of section 11-13 not constructed. $465 per acre development cost. Not feasible.
4.	Schoolie Flat	11-9.7 11-13	5,011	Part of 5,870 acre unit. See No. 2.
5.	Schoolie Flat	11-9.8 11-14 12-5.9 App.XII-E.2	5,011	Part of 7,017 acre supplying Schoolie Flat, Simnasho, Miller Flat, Dry Creek, and 475 acres on Sidwalder Flat not covered by Mill Creek Diversion. See No. 7. Joint use from power canal traversing Sidwalder and Miller Flat. Either simultaneous operation or non-simultaneous operation with power. Non-simultaneous operation pro-rated cost is attractive for irrigation, but doubtful for power.
6.	Sidwalder Flat	11-9.12 11-10	1,079	Unregulated diversion from Mill Creek. Enlargement of existing main canal, and lateral extension.
7.	Sidwalder Flat	11-9.12	1,586	Regulation of Mill Creek by storage at headwater lakes. Estimated development cost less than $170 for acreage in excess now assessed.
8.	Miller Flat	11-9.10 11-14 12-5.9 App.XII-E.2	485	Part of No. 5. Appears to be only feasible method of obtaining water. Mill Creek water more economically diverted to Sidwalder Flat.
9.	Dry Creek	11-9.15 11-14 12-5.9 App.XII-E.2	829	Part of No. 5. Appears to be only feasible method of obtaining water. Mill Creek water more economically diverted to Sidwalder Flat.

10.	Metolius Bench	11-9.17	1,435	Diversion from Whitewater River for 2,973 acres on Metolius and Tenino Bench, Dry Hollow, and Seekseequa Creek. High canal construction cost appears prohibitive.
11.	Metolius Bench	11-9.20 12-5.11 App.XII-E.2	1,435	Joint use of power canal by diversion from Tunnel penstock. Conflict in use of water. Does not appear feasible.
12.	Tenino Bench	11-9.21	1,273	Part of No. 10.
13.	Seekseequa Creek	11-9.23	175	Part of No. 10.
14.	Seekseequa Creek	11-9.24	unknown	Small storage dams on creek having limited storage capacity. Independent systems of 10 to 20 acres.
15.	Deschutes Valley	11-9.25	250	Independent pumping plants. Pumping direct from river.
16.	Tenino Creek Shitike Creek	11-9.26	500	430 acres be pumping from Shitike Creek. 2 pumping sites. 70 acres now assessed are outside of unit.
17.	Warm Springs	Existing	296	Units same as now exist.
18.	Simnasho	11-9.27 11-13	209	Run-off or waste from development at Schoolie Flat by either No. 4 or No. 5.

Section 11-10: Potential Irrigation by Extension of Unregulated Mill Creek Unit.

11-10.1 Description. Of the six existing units on the project, the Mill Creek unit appears to be the most feasible for immediate extension without major revision to present facilities. The unit has a source of water, that if managed properly, can irrigate more acreage than now being irrigated, or being assessed. The unit has the lowest operation and maintenance charges per acre of any unit on the project. It is potentially the largest of any of the existing units.

11-10.2 The plan for extension of this system would use the existing diversion site, and continue to receive unregulated stream flow from Mill Creek. The existing main canal would be enlarged to handle increased discharges. It would be extended, and the lateral systems constructed to serve lands not now irrigated or assessed.

11-10.3 Irrigable Lands. There are 2,069.5 acres of land mapped by the recent soil survey on Sidwalder Flat that are considered irrigable. See Appendix XI-D1. These lands all lie below the present main canal, and are of either class I, II, or III. An additional 470 acres of class IV land have been mapped which could possibly be irrigated with some success. The class II lands are approximately 75% of the lands considered to be irrigable.

11-10.4 Water Supply. Very little data are available regarding the discharge of Mill Creek. Miscellaneous measurements were taken during the summer 1915. See Appendix VI-F. During this time, stream measurements were obtained continuously on the Warm Springs River, and on Shitike Creek. Continuous measurements during other years of these two streams indicate that stream discharge throughout the reservation was abnormally low during the summer of 1915. Miscellaneous measurements of Mill Creek available probably indicate discharges less than normal.

11-10.5 Shitike Creek has its headwaters in the high regions of the Cascades, as does Mill Creek. The miscellaneous measurements taken at Mill Creek near the Old Mill Ranger Station are compared to those taken simultaneously at Shitike Creek near its mouth. The average discharge ratio of 0.62 is computed from tabular data shown in Table 11-10.5A. The discharge ratio is used to compute average monthly discharges of Mill Creek at the Old Mill Ranger Station as tabulated in Table 11-10.5B. The diversion is within a mile and one-half of the gaging station. Discharges at the two locations are assumed to be the same.

Table 11-10.5A Discharge Ratio, Mill Creek - Shitike Creek

Mill Creek Station: Sec. 20, T.85., R.10E. (Appendix VI-F)
Shitike Creek Station: Sec. 26, T.95., R.12E. (Appendix VI-C)

Date	Measured Discharge, cfs.		Ratio
	Mill Creek	Shitike Creek	
June 9, 1914	71.6	100	0.72
July 1, 1914	49.2	100	0.49
June 5, 1915	71.0	118	0.60
June 8, 1915	63.0	90	0.70
June 10, 1915	58.0	84	0.69
June 17, 1915	52.0	71	0.73
June 25, 1915	48.0	62	0.77
June 29, 1915	46.2	71	0.65
July 6, 1915	45.0	80	0.56
July 7, 1915	44.0	80	0.55

July 8, 1915	45.0	80	0.56
July 9, 1915	45.0	90	0.50
July 29, 1915	38.0	62	0.61
July 30, 1915	38.0	62	0.61
Average	51	82	0.62

Average discharge ratio, Mill Creek/Shitike Creek. 0.62

Table 11-10.5B Computed Discharge of Mill Creek

Month	Average measured discharge of Shitike Creek, cfs.	Computed Average discharge of Mill Creek, cfs.	70% of computed average, cfs. 1/
May	157	97	68
June	143	89	62
July	108	67	47
August	67	42	29
September	61	38	27

1/ 70% of average discharge is used as source available during dry years. Records from Shitike Creek, Appendix VI-C, show that during the months of August and September that in only 16% of the years is monthly run-off less than 70% of average.

11-10.6 The unregulated discharge of Mill Creek during the normal irrigating season is determined to vary from a computed average discharge of 90 cubic feet per second during May and June, to approximately 40 cubic feet during the months of August and September. To obtain a reasonable maximum benefit from unregulated diversion of such a variable stream, the capacity of the main canal should be larger than the minimum discharge of Mill Creek. The successful operation of an irrigation unit relying upon maximum use of a unsustained and unregulated diversion requires heavy use of available water during the early summer. To obtain the maximum benefit from available water, irrigation should begin early in the season, to build up soil moisture during the time the system has its best capacity. The agriculture in an expanded irrigation program on Sidwalder Flat is assumed to be mainly for forage production, and can advantageously use the earlier irrigation.

11-10.7 A main canal having a capacity approximately equal to the average discharge of July, August and September is recommended. A main canal allowing diversion of approximately 45 cubic feet per second could flow full during the early part of the irrigating season. From approximately the middle of July to the end of the season the canal could carry the entire unregulated stream flow, less residual for stream flow below the diversion. A minimum residual of 5 cubic feet per second is used for design in this study. For computing maximum system size it is assumed that during 86% of the years that discharge of Mill Creek exceeds 70% of average discharge. With 70% of average discharge being considered available, less minimum residual flow, this would mean that for the maximum irrigable design acreage the water would be in short supply during August and September for 16% of the years. See Table 11-10.5B.

11-10.8 For a study of water supply at the unregulated diversion, the water available is assumed to be due to stream run-off occuring during a 110 day period beginning June 1. If the minimum residual stream discharge below the diversion is 5 cubic feet per second, water disposition at the diversion from unregulated discharge into a main canal having a capacity of 45 cubic feet per second is shown in Table 11-10.8A.

Table 11-10.8A Water Disposition from Unregulated Diversion

Month	70% average unregulated run-off, cfs.	Average diversion cfs.	Average residual below diversion, cfs.	Average diverted run-off ac: ft.
June, 30 day	62	45	17	2,678
July, 31 day	47	42	5	2,583
Aug., 31 day	29	24	5	1,476
Sept., 18 day	27	22	5	7,522

11-10.9 The following disposition of water is assumed:

Annual farm application	3.4 ac.-ft/ac.
Canal loss	25%
System run-off and waste Assumed to be heavy in early part of season due to source of water being unregulated.	35%
Water conveyed by main canal (7,522) (0.75)	5,642 ac.-ft.
Useable water (5,642) (0.65)	3,667 ac.-ft.
System capacity (3,667) ÷ (3.4)	1,079 ac.

11-10.10 Design Summary. The water supply from unregulated diversion from Mill Creek appears adequate to serve 1,079 acres on Sidwalder Flat. This is approximately 238 acres more than now being assessed, and about three times that now being irrigated. It is nearly equal to 75% of the class II land mapped on Sidwalder Flat, and is about 50% of all land on Sidwalder mapped as irrigable (class I, II, and III).

11-10.11 The principal features of the plan would be an enlargement of existing diversion turnout at Mill Creek, enlargement of the existing main canal to handle a 45 cubic feet per second capacity, and extension of the canal and lateral system to cover new lands brought under irrigation. Minimum design residual flow below diversion is 5 cubic feet per second.

11-10.12 Estimated Cost. Estimated cost of development is:

Main canal enlargement to 45 cfs, 8 mi. 3.0 yd.^{3} per lin. ft., @ \$0.35 per yd.^{3} (3.0)(0.35)(8.0)(5280)	\$44,352.00
Main canal structures 15% of excavation	6,652.00
Extension of new canal and lateral system for lands in excess of those now assessed 238 ac. @ \$125.00	29,750.00
Total cost	\$80,754.00
Unit cost of new construction Apply cost of increased main canal capacity to entire unit (\$51,004.00) ÷ 1079	47.00
Canal and lateral extension	125.00
Unit cost	\$ 172.00 per acre

11-10.13 Unit cost of lateral extension is assumed to be quite high, \$125.00 per acre, as considerable non-irrigable lands must be traversed by lateral systems.

11-10.14 Feasibility. The plan would provide better service to the 842 acres now assessed. Approximately 255 acres of additional land could be brought into irrigation at a pro-rated cost of approximately \$172.00 per acre. The entire plan is contingent upon unregulated discharge of Mill Creek. The run-off measurements used as a basis of this study are computed by ratio with Shitike Creek. Additional stream measurements are needed to verify computed discharge of Mill Creek.

11-10.15 The success of the plan requires improvement of irrigation and water control methods now found on the reservation. The full use of diversion from unregulated diversion of Mill Creek provides little flexibility in irrigation methods or time of application. From a standpoint of overall economy, the plan appears feasible. However, with little additional expense the discharge of Mill Creek can be regulated. A design providing regulated diversion from Mill Creek is described in section 11-11, and is preferred over unregulated diversion.

Section 11-11: Potential Irrigation by Extension of Regulated Mill Creek Unit.

11-11.1 Description. Extension of the existing Mill Creek unit having a diversion from a regulated discharge of Mill Creek, could be obtained by the construction of three small dams at the three lakes forming the headwaters of Mill Creek. Storage would allow a more sustained flow of Mill Creek, and contribute greatly to the flexibility of the unit over that possible with unregulated flow. See section 11-10.

11-11.2 A dam eighteen to twenty feet high at the outlet of Trout Lake, and dams about five feet in height at the outlet of Island Lake and Dark Lake would increase the combined capacity of the lakes by about 2,000 acre-feet. This added storage would be entirely available to increase the discharge of Mill Creek during late summer. It is assumed that loss of water as it flows down Mill Creek in the natural channel is negligible, and that the full 2,000 acre-feet is available at the diversion. The storage behind the dams would be recharged during the early spring months, and would have no effect upon the natural discharge of Mill Creek during the early part of the irrigating season. Any added regulation due to rainfall occuring at the summit during irrigating season is neglected in this study.

11-11.3 The storage capacity at the three lakes was determined by planimeter area from U. S. Geological Survey Quadrangle maps, causing the accuracy of the reported storage to be questioned. The amount of embankment required to construct the three dams of the approximate described size is not known. Henderson, former Irrigation Engineer, U. S. Bureau of Indian Affairs, Portland Area Office, has described the outlets of these lakes as topographically well suited for construction of small dams. The dams would be relatively inexpensive.

11-11.4 Irrigable Lands. Lands irrigated by this plan of development are on Sidwalder Flat, the soil capabilities reported in paragraph 11-10.3.

11-11.5 Water Supply. A discussion of the unregulated discharge for Mill Creek appears in paragraph 11-10.4. Water disposition at the diversion from regulated discharge into a main canal having a capacity of 45 cubic feet per second is shown in Table 11-11.5A. The minimum design residual below the diversion is 5 cubic feet per second, as it was in plan discussed in section 11-10.

Table 11-11.5A Water Disposition by Regulated Diversion

Month	70% Av. unreg. runoff, cfs.	Av.unreg. diver.-streams, cfs.	Av. reg. from lakes, cfs.	Av.total reg. diver., cfs.	Av. residual flow, cfs.	Av.reg. from lakes, acre-ft	Total Av. reg. diver. acre-ft
June, 30 day	62	45	0	45	17	0	2678
July, 31 day	47	42	3	45	5	185	2767
Aug.,31 day	29	24	19	43	5	1168	2644
Sept.,18 day	27	22	20	42	5	714	1500
Total						2067	9589

11-11.6 It is assumed that system run-off and waste for the regulated system is reduced from the 35% used in the unregulated system of section 11-10. A runoff of 25% is used in this study, as regulation provides improved flexibility of operation. The following disposition of water is computed.

Annual farm application	3.4 ac.-ft/ac.
Canal loss	25%
System runoff and waste	25%
Water conveyed by main canal (9,589) (0.75)	7,192 ac.-ft.
Useable water (7,192) (0.75)	5,394 ac.-ft.
System capacity (5,394) ÷ (3.4)	1,586 acres

11-11.7 Design Summary. The addition of 2,000 acre-feet of storage at the headwaters of Mill Creek provides increased diversion into the main canal during the late summer. Average unregulated diversion during August and September was increased from 25 and 22 cubic feet per second to 43 and 42 cubic feet per second, respectively. This allows 1,586 acres to be irrigated by the system. The only structural change to the system is the construction of the three small dams on the three headwater lakes, with extension to the canal and lateral system as described for the plan of section 11-10. Main canal size remains the same.

11-11.8 Feasibility. No cost data are suggested for the construction of the three small dams. For the added benefit to the system as described in section 11-10 and the possibility of adequately serving an additional 507 acres, the additional cost of regulation is undoubtedly justified. The system as described in this section could irrigate a total of 1,586 acres, this is approximately 484 acres less than the total acreage mapped on Sidwalder Flat by the recent soil survey as being within the first three classes.

11-11.9 The conclusion is made that expansion of the Mill Creek unit on Sidwalder Flat using regulated discharge and diversion is the most favorable method of development. Power development as described in paragraph 12-5.4 should not be allowed to conflict with the agricultural uses of this stream during the irrigation season. It is unlikely that the construction cost of the three small dams would exceed the benefits of improved irrigation performance to the 1079 acres covered in plan of section 11-10, and to the benefits obtained from possible coverage of an additional 507 acres. If storage were to be developed at Schoolie Flat, see paragraph 11-14.1, and those waters channeled across Sidwalder Flat to serve either irrigation, or power, or both, the drainage from Mill Creek could be used for supplying water at Sidwalder Flat lying above the Miller Flat power canal. The conclusion of section 11-14 is, however, that a coordinated power and irrigation development from storage on Schoolie Pasture does not appear attractive to power development. In any proposed plan of development, regulated run-off of Mill Creek for irrigation on Sidwalder Flat is recommended.

11-11.10 The amount of available storage at the headwater lakes is not accurately known. It is also possible that additional storage could be available by increasing slightly the height of the outlet dams. Because the available water supply is critical in determining the maximum irrigable acreage on Sidwalder Flat by this method of irrigation, additional information is needed on natural run-off of Mill Creek, and the topography of the headwater lakes. Permeability of the dam materials would not be a problem, as moderate amounts of seepage would not adversely affect the regulation of Mill Creek.

Section 11-12: Potential Irrigation By Tenino Pumping Unit.

11-12.1 Description. A plan for irrigating the lower Tenino Valley has been proposed by the Bureau of Indian Affairs. Preliminary design has been completed for the unit. The hydraulic characteristics and location of main canals are shown by a map (74), Tenino Unit Irrigation System, Bureau of Indian Affairs, Irrigation Division, Portland, Oregon, March 4, 1952. Construction proposed by the Bureau of Indian Affairs was to commence in 1954, but was abandoned due to lack of funds.

11-12.2 Water for the proposed unit is to be obtained from unregulated diversion at Shitike Creek, 6,000 feet upstream from the mouth of Tenino Creek. Diverted water would then flow in the rehabilitated existing Shitike ditch, entering the north side of the Tenino valley, and received by a pumping forebay at the elevation of 1535 feet above sea level at a location approximately 2,400 feet southwest of the mouth of Tenino creek. The pump at this location would lift the water up the north side of valley to two canals, designated as Canal A and Canal B.

11-12.3 The inlet to Canal A would be at an elevation of 1,670 feet. This canal, having a design capacity of 18 cubic feet per second, flows westerly on a gradient of 0.0002 until it intercepts Tenino Creek approximately 12,000 feet upstream from its confluence with Shitike Creek. The canal then would cross to the south side of Tenino Creek by a wooden flume, and continue to flow in an easterly direction, having a discharge of 13 cubic feet per second. Canal A would then flow easterly on the south side of Tenino Creek and Shitike Creek, located at an elevation of approximately 1660 feet above sea level. Design canal capacity progressively reduces, the canal terminating on the south side of Shitike Valley, about 8,000 feet east of the mouth of Tenino Creek. At the end of Canal A, a drop structure would deliver water to a canal, designated by Canal X. Canal X would be 4,000 foot long, located on the 1,560 foot contour, and having a design capacity of 3 cubic feet per second.

11-12.4 The inlet to Canal B would be at an elevation 1,600, being served from the same pump and pump discharge pipe supplying Canal A. Canal B would roughly parallel Canal A for a short distance, flowing with a design capacity of 3 cubic feet per second. Canal B would then cross to the south side of Tenino Creek on a wooden flume at a point about 7,500 feet from the mouth of the creek. The canal on the south side of Tenino Creek would be approximately 800 feet south of the Tenino Creek road. Waste from the canal would discharge into Tenino Creek.

11-12.5 A pumping forebay on Canal A, located on the north side of Tenino Creek and about 800 feet upstream from the wooden flume crossing that marks the most westerly projection of Canal A, would deliver water to a canal designated as Canal C. The forebay, located on Canal A, would be at an elevation of 1,668 about sea level. A pump would lift in water to the inlet of Canal C, having an inlet elevation of 1728, and a design capacity of 6.5 cubic feet per second. Canal C would flow westerly on the north side of Tenino Creek until it intercepts the creek approximately 3,500 feet further upstream. The canal would then cross the creek by a short conduit, than proceed easterly with a design discharge of 4 cubic feet per second. Canal C would terminate on the 1,720 foot contour, approximately due south of its inlet.

11-12.6 Irrigable Lands. Lands covered by the unit are classified by the recent soil survey as follows:

Class I	38.8 ac.	Class IV	196.8 ac.
Class II	50.3 ac.	Class VI	42.6 ac.
Class III	344.7 ac.	Class VII	320.9 ac.

The lands of class I, II, and III are considered to be irrigable. They are all below the elevation of the canal system. No terrain problems exist to prohibit their being served. The total of these irrigable lands is approximately 430 acres. It is possible that some of the 196.8 classified as being Class IV could be satisfactorily irrigated.

11-12.7 Water Supply. At its mouth, Shitike Creek has a minimum average monthly discharge of approximately 60 cubic feet per second. Discharge at the diversion point is probably nearly the same. The minimum average monthly discharge is ample for the system, and for diversion residual for other diversions or uses of lower Shitike Creek.

11-12.8 The system allows accurate regulation and disposition of irrigation water. The source of water is adequate, and the short canal systems served by pumping lifts provide a means of attaining efficient irrigation application. Because of the operation costs of this system chargeable to power, high irrigation efficiencies within this system are absolutely necessary for economic operation.

11-12.9 Power Cost. The average pumping lift for the entire unit is approximately equal to the 135 feet vertical lift required to pump into Canal A. Canal B and Canal C have lifts that are 65 feet less and 60 feet greater, respectively, and each cover approximately 10% of the entire unit. Assuming overall electrical power cost at $0.007 per kw.hr, the power cost to pump one acre-foot of water from the diversion into Canal A is $1.35. Pumping efficiency of 70% is assumed.

11-12.10 Pumping sites. Two pumping sites are required. The discharge conduit serving Canal A and Canal B is approximately 1,200 feet long. If 22" steel pipe is used throughout the length and if both canals operate simultaneously, the hydraulic power requirement at 70% efficiency is 450 horsepower. The discharge conduit serving Canal C is approximately 350 feet long. If 12" steel pipe is used to supply Canal C, hydraulic power requirement at 70% efficiency is 75 horsepower. Manning's coefficient, n = 0.013, is used.

11-12.11 Estimated Cost. Estimated cost of development is:

Main canal construction, 54,000 ft.	
54,000' @ $1.00	$ 54,000.00
Flume, wooden, 180 ft.	
180' @ $6.00	1,080.00
Structures, checks, turnouts	
15% of excavation charges	8,100.00
Pump site	
Pumps, motors installed.	
525 h.p. @ $60.00	31,500.00
Conduit	
22" x 1,200' @ $10.00	12,000.00
12" x 350' @ $5.00	1,750.00
Diversion rehabilitation	1,000.00
Lateral construction, including rehabilitation of existing system	
400 ac. @ $50.00	20,000.00
Total	$129,430.00
Unit Cost	
129,430 ÷ 430	$301.00 per acre

11-12.12 Feasibility. Water from Shitike Creek is the only available source for irrigation in lower Tenino Valley. Because much of the land lies above gravity diversion, pumping is required. The system as described in section 11-12 appears to be feasible. The main canal system nearly completely bounds the area irrigated, and would be a major cost. It would be constructed on relatively steep cross-slopes, and would require especially careful earth compaction to minimize seepage. The pumping cost per acre based on a three foot application and 135 foot lift would be about $4.00 annually, and is not considered prohibitive. It would be expected that considerable pumping cost could be avoided by careful re-use of field waste water from higher fields. A portion of water assessment should be based on metered consumption.

11-12.13 Lands lying in the valley to the west of the system could be irrigated by construction of additional pumps at Canal C. Within the first mile approximately 25 acres of Class II and 40 acres of Class III land are mapped. A limiting factor to bring water to these lands is the high pumping lift required. The gradient of Tenino valley becomes steeper beyond the westerly limit of Canal C. About 35 acres fall within the first one-half mile and would require a total vertical pumping lift of approximately 250 feet. Pumping costs per acre-foot of water would be about $2.50. The remaining additional land would require a total vertical lift of about 300 feet, with pumping costs of $3.00 per acre-foot of water. The justification of pumping costs exceeding $2.50 per acre-foot of water is questionable.

11-12.14 The per acre construction cost of ditches and laterals for the unit would be expected to be less than normal, the reason being the close proximity of the entire acreage in the system to the main Canals, A, B, C, and X. The unit is compact, that is there are not extensive acreages of non-irrigable lands within the canal system. This would require only little canal footage passing through unproductive lands, and have the desired effect of reducing maintenance problems. The side-hill canals would require spillway sections for protection from storm run-off from the hills above the canal.

11-12.15 The pumping unit would not affect the irrigation of lands on the Shitike valley floor now being irrigated by gravity diversion, as irrigation to these lands could still be more economically performed from existing canals.

Section 11-13: Potential Irrigation from Upper Warm Springs River for the Island, Simnasho, and Schoolie Flat, no Power Coordination.

11-13.1 Description. Both the Island and Schoolie Flat are plateau lands that are isolated from sources of irrigation water by very deeply cut canyons. The problems of securing irrigation water for these two areas are many. The Warm Springs River offers the only source of water, it flows in a canyon approximately 500 to 600 feet below the plateau of the Island. The river is separated from Schoolie Flat by the Island and by the Beaver Creek canyon.

11-13.2 Water can be obtained from a diversion of the Warm Springs River near the outlet of Schoolie Pasture. A diversion near the outlet of Schoolie Pasture at an elevation of 2,700 feet above sea level would be sufficiently high to bring water to the Island and permit a siphon across Beaver Creek. A canal on the north side of Warm Springs River would receive the diverted water. The canal would enter the Island near the southeast corner of Sec. 1, T. 7 S., R. 10 E., and proceed southeasterly on the Island in such a location to maintain maximum elevation. The elevation of the main canal on the Island at approximately the west quarter corner of Sec. 23, T. 7 S., R. 11 E. appears from the U. S. Geological Quadrangle map to be approximately 2640 feet above sea level. At this point the canal would branch, one section providing water to the irrigable lands lying to the south on the Island, and the other section entering a low pressure conduit to proceed easterly to serve Schoolie Flat and Simnasho.

11-13.3 A major physical obstacle in this system is the Beaver Creek Canyon that must be crossed by a siphon. It would be advantageous to cross the canyon in a location as far to the north as possible, as Beaver Creek canyon becomes increasingly deep further to the south. At a location near the north line of Sec. 23, T. 7 S., R. 11 E. the canyon appears to be approximately 400 feet deep, the bottom being at an elevation of 2,200 feet above sea level. A siphon in this location having inlet and outlet at an approximate elevation of 2,600 would be 2,000 feet long. The outlet of the siphon would not be at an elevation sufficient to irrigate Schoolie Flat. A canal system on Schoolie Flat would require pump lifts. Pumping to an elevation of 2,800 feet above sea level would provide for gravity irrigation commanding nearly 90% of all land mapped on Schoolie, and approximately 95% of the land classified as irrigable, that is class I, II, or III.

11-13.4 To reduce pumping costs on Schoolie Flat the open channel on the Island would be located on as high ground as possible. Low pressure conduit adjacent to the siphon inlet on the Island and adjacent to siphon outlet on Schoolie Flat would assist in preserving head. To keep siphon construction costs reasonably low, it would be desired to have the siphon diameter be as small as practical within reasonable siphon friction losses. The low pressure conduit on Schoolie Flat would discharge into an open channel that would appear from the topographic maps to be at an elevation of about 2,600 feet above sea level. The canal would follow the contour along on the north edge of Schoolie Flat and south of Quartz Creek. The canal would discharge into a pumping forebay near the 2,600 foot contour in a drainageway located 1,000 foot south and 1,000 foot west of the northeast corner of Sec. 20, T. 7 S., R. 12 E., and being about one-quarter mile east of Simnasho road. A discharge pipe having a length of approximately 6,000 feet and bearing easterly would terminate at a canal having an elevation of 2,800 feet above sea level at location 7/12 - 21B.

11-13.5 Outlets along the discharge pipe would serve four main canals having elevations of approximately 2,650, 2,700, 2,750, and 2,800 feet above sea level. The four canals would serve lateral systems covering the entire Schoolie Flat unit.

11-13.6 The forebay provides a source of water for an extension of the existing Simnasho irrigation unit. Water released from the forebay would enter Simnasho valley near the Simnasho road, at a location where it would be available for the Simnasho irrigation unit. This has great value to the lands which lie in Simnasho Valley, for water from Quartz Creek is insufficient for fully developed irrigation.

11-13.7 Irrigable Lands. Lands covered by the canal system are classified by the recent soil survey of the Bureau of Indian Affairs, Appendix XI-D.1, as follows:

Table 11-13.7A Land Classification Acreage Within Unit.

Area	Class I	Class II	Class III	Class IV	Class VI	Class VII
Schoolie Flat	20.5	4100.0	890.0	276.4	327.0	6150.0
Island	--	614.5	37.5	--	--	1944.3
Simnasho	--	47.3	162.2	433.2	--	35.0
Total	20.5	4761.8	1089.7	709.6	327.0	8129.3

Total of Class I, II, and III = 5,872.0 acres.

11-13.8 Lands considered to be irrigable on this project are all Class I, II, and III acreages. It is probable that some of the Class IV lands could be irrigated successfully. This particularly is true in the Simnasho area, where much of the Class IV is located on the valley floor of Quartz Creek.

11-13.9 The project would be compact, that is, a high ratio of irrigable lands to total lands covered. This would have the effect of favorable development cost for lateral systems, particularly on Schoolie Flat.

11-13.10 Schoolie Flat contains about 50% of the acreage on the reservation to which water could be feasibly delivered. A distinguishing characteristic of the Flat is the high percentage of mapped lands of Class II. The soils are deep. The topography is favorable for distribution system construction, being relatively even, and not broken by numerous waterways and other surface irregularities common to much of the reservation.

11-13.11 Water supply. The minimum daily discharge recorded for the Warm Springs River near Hehe Butte is 97 cubic feet per second. The minimum average monthly discharge occurs during September, being 121 cubic feet per second. The discharge near the outlet of Schoolie Pasture is assumed to be 90% of that at Hehe Butte. 80% of average monthly runoff is available during August and September during 90% of the years. There are no major streams tributary to the river within these two locations, the river being effluent. It is assumed that the following discharge occurs at the Warm Springs River at the Diversion:

Table 11-13.11A Discharge of Warm Springs River.

Month	Av. Meas. Discharge near Hehe Butte, cfs.	Discharge Factor	Computed Av. Discharge near Schoolie P. cfs.	80% Average Computed Discharge Schoolie P. cfs.
May	278	0.90	250	200
June	198	0.90	178	142
July	137	0.90	123	98
August	125	0.90	112	90
September	121	0.90	109	87

11-13.12 Approximately 5,780 acres of Class I, II, and III are within the unit. The total of 5,870 acres is used as a basis of computing water requirements.

11-13.13 Unregulated Diversion. A minimum residual of 20 cubic feet per second is assumed below the diversion for unregulated flow of Warm Springs River. The main canal would traverse lands suspected of high permeability. A 35% loss in main canal is assumed. The canal material would contain considerable basaltic materials requiring compaction during construction to maintain losses as low as 35%. For a study of water supply at the unregulated diversion, available supply is assumed to be due to stream runoff occuring during a 110 day period beginning June 1. The disposition of unregulated diversion on the unit is assumed:

Annual Farm application	3.4 ac.ft./ac.
Canal loss	35%
System runoff and waste Assumed to be heavy in early part of season due to unregulated source of water	35%
Total annual water requirement at farm (5,870) (3.4)	19,960 ac.ft.
Total annual water requirement at lateral (19,960) ÷ (0.65)	30,710 ac. ft.
Total annual water required at diversion (30,710) ÷ (0.65)	47,200 ac.ft.

11-13.14 Irrigation of the 5,870 acres within a 110 day period with system losses assumed in 11-13.13 requires sustained diversion into the main canal of approximately 210 cubic feet per second. This is impossible with unregulated diversion, and is rejected.

11-13.15 Regulated Diversion. Regulation at the diversion is necessary to comply with anticipated total demand of the project. A dam at the site described in paragraph 11-3.9 having a storage capacity of 30,000 acre-feet is suggested. This would require a dam having a height of approximately 35 feet. With regulation, system loss is assumed to be reduced to 30%. The following disposition of water is computed:

Annual farm application	3.4 ac.ft./ac.
Canal loss	35%
System runoff and waste	30%
Total annual water requirement at farm (5,870) (3.4)	19,960 ac.ft.
Total annual water requirement at lateral system (19,960) ÷ (0.70)	28,510 ac.ft.
Total annual water requirement at diversion (28,510) ÷ (0.65)	43,900 ac.ft.

11-13.16 The required regulated capacity of the canal at the Schoolie Pasture diversion is assumed to be 200 cubic feet per second, providing a 43,700 ac. ft. runoff in 110 days. Water disposition at the regulated diversion is computed in Table 11-13.16A.

Table 11-13.16A Regulated Diversion at Schoolie Pasture

Month	80% Av. unreg. runoff, cfs.	Av. res. below diver., cfs.	Av. Contribution from stream, cfs.	Av. Contribution from stream, ac.-ft.	Av. contribution from storage, cfs.	Av. contribution from storage, ac.-ft.
June, 30 day	142	20	122	7,260	78	4,641
July, 31 day	98	20	78	4,796	122	7,502
Aug., 31 day	90	20	70	4,304	130	7,994
Sept, 18 day	87	20	67	2,392	134	4,784
Total				18,752		24,921
Combined Total Runoff					43,673 ac.-ft.	

11-13.17 The 30,000 ac.-ft. reservoir would have a 5,000 ac.-ft. residual at end of the 110 day continuous diversion of 200 cubic foot per second. It is assumed that 80% of the total main canal loss would occur upstream from the inlet to the low pressure conduit on the Island. This would require main canal capacity before the conduit inlet and before the Island diversion to be 144 cubic feet per second.

11-13.18 Island Diversion. The diversion canal to the Island distribution system would be approximately four miles long and sustain losses of 15% of its intake. Lateral waste, and runoff is estimated to be 30%. The disposition of water on the Island is computed:

Annual farm application	3.4 ac.-ft.
Canal loss	15%
System runoff	30%
Total annual water requirement at farm for 650 acres (650) (3.4)	2,210 ac.-ft.
Total annual water requirement at lateral system (2,210) ÷ (0.70)	3,160 ac.-ft.
Total annual water requirement at diversion (3,160) ÷ (0.85)	3,720 ac.-ft.

11-13.19 The required regulated capacity of the Island diversion from the main canal would be 17 cubic feet per second, providing a 3,720 ac.-ft. runoff in 110 days. A discharge of 127 cubic feet per second remains in the canal to be carried across Beaver Creek by the low pressure conduit and the siphon.

11-13.20 Beaver Creek Crossing. The inlet to the low pressure conduit should be located on as high a ground as practical with reasonable distance to the siphon inlet on the west canyon wall to Beaver Creek. The low pressure conduit inlet elevation would be approximately at an elevation of 2,640 feet above sea level and have a length of 1,000 feet. Construction of the siphon would be a major cost of the project. Its actual location and design requires a detailed survey of the area to be crossed. From the U. S. Geological Quadrangle maps, the most favorable location appears to be in the north half of Sec. 23, have a total head differential of about 400 feet and a length of 2,000 feet. Low pressure conduit at siphon outlet would be short, around 500 feet. To keep siphon construction cost to a minimum amount consistent with the added pumping cost on Schoolie Flat, an allowable 35 feet of friction loss is assumed in the 2,000 foot siphon.

11-13.21 The computed diameter of the 2,000 feet of siphon and 1,500 feet of low pressure conduit, is based on an assumed Manning's coefficient of $n = 0.013$, and acting hydraulic slopes of 0.018 and 0.003 for siphon and penstock, respectively. The computed diameter of the siphon is 42 inches, the diameter of the low pressure penstock being 60 inches.

11-13.22 Water discharging from the low pressure conduit at 127 cubic feet per second at the west edge of Schoolie Flat near the northeast corner of Sec. 23, T. 7 S., R. 11 E., would flow north in an open channel at an elevation of approximately 2,600 feet above sea level. Approximately 10% of the intake capacity would be lost to seepage in this three and one-half miles of canal. The three and one-half mile section of canal terminates at the forebay located east of the Simnasho road, and described in paragraph 11-13.4. Design discharge into the forebay would be 114 cubic feet per second.

11-13.23 Diversion at Forebay to Simnasho. Approximately 210 acres of Class II and III land could be irrigated at Simnasho valley from gravity diversion from the Schoolie Flat pumping forebay. This water would command by gravity system all Class II and III lands mapped by the recent soil survey. The forebay would serve as a spillway for water not being pumped for the Schoolie Flat system. Therefore, Class IV lands in Simnasho would often have access to spilled water at the forebay, available at no extra operation charges save that for additional lateral construction, operation and maintenance at Simnasho.

11-13.24 Pumping Water at Schoolie Flat Forebay. Successful operation of the Schoolie Flat unit would require rigid control of irrigation water within distribution laterals and at the farm. All these irrigable lands on Schoolie Flat would require pumped water, at heads varying from 50 to 200 feet. Poor irrigating efficiencies at lands receiving pumped water would result in prohibitive pumping costs. For this reason the distribution canal system on Schoolie Flat must have a capacity to deliver the high application rates needed to irrigate efficiently. It means a well laid out system that is maintained to high standards of performance. It is likely that the lower lands of the Flat would benefit considerably from waste water intercepted from higher lands.

11-13.25 The capacity of the pumps at the forebay would be designed to accommodate the entire canal discharge into the forebay. Approximately 75% of irrigable lands appear to lie between the 2,700 and 2,800 foot contour, but are considerably scattered at the higher elevations. Pumps and discharge pipe are computed on the assumption that 100% of the forebay intake is pumped through the first 4,000 feet of pipe at a vertical lift of 100 feet, 75% of the forebay intake is pumped through the first 5,000 feet at a vertical lift of 150 feet, and 25% of forebay intake passes entire 6,000 feet at a 200 foot lift. A power schedule for the pumping plant is shown in Table 11-13.25A. Manning coefficient of n = 0.013 and an overall pump operating efficiency of 70% is used.

Table 11-13.25A Pump Plan at Schoolie Flat.

Section	Discharge cfs.	Pipe diameter inch	Friction loss, feet	Static lift, feet	Total Pumping hd. ft.	Required h.p. 70% Eff.
First 4000'	114	54	13	100	113	2,100
Next 1000'	56	36	7	50	57	520
Last 1000'	28	28	7	50	35	160
Total						2,780

<u>11-13.26</u> <u>Design Summary.</u> The following is a summary of design of the Upper Warm Springs Unit:

Storage.
Rock and earth dam on Warm Springs River near outlet of Schoolie Pasture. 44,000 cu. yd. Height 35 feet. Crest length 400 feet. Crest width 15 feet. 2:1 slopes. 30,000 acre-feet.

Schoolie Pasture diversion.
At 2,700 foot elevation at 7/10-8F on left bank of river. Inlet capacity 200 cfs. Enters north end of the Island, terminating at pressure pipe at 7/11-23F. Length of open channel 11 miles. Loss in diversion canal 56 cfs.

Island Diversion.
Diversion of 17 cfs. at 7/11-23F for Island. 4 mile main canal with laterals for 650 acres.

Beaver Creek siphon.
127 cfs. into 5' x 1000' low pressure steel conduit at 7/11-23F. 127 cfs. into 42" x 2000' steel siphon on west edge of canyon at 7/11-23G. 127 cfs. into 5' x 500' low pressure steel conduit at 7/11-23A.

Schoolie Flat forebay canal.
Begin 127 cfs. canal at 7/11-23A at west edge Schoolie Flat, 2600' above m.s.l. 3½ mile canal with 13 cfs. seepage terminates at forebay 7/12-20B.

Simnasho diversion.
Gravity diversion from forebay to 200 acres in Simnasho valley.

Schoolie Flat pump.
2,780 hydraulic horsepower, 70% efficiency. Multiple units parallel connected. 54" x 4000' steel, 36" x 1000' steel, 28" x 1000' steel discharge.

Schoolie Flat distribution.
Ditch and lateral system to approximately 5,000 acres of land classified as I, II, or III.

<u>11-13.27</u> <u>Estimated Cost.</u> An estimate of construction cost of the unit is:

Schoolie Pasture dam.	
Embankment, rock and earth. 44,000 yd.^{3} @ \$1.75	\$ 77,000.00
Spillway, diversion.	
20% embankment	15,400.00

Fishway	
25% embankment	19,250.00
Diversion canal, 11 mi.	
Excavation in rock, sidehill, trapezoidal concrete lining. 1 mi. 5280 ft. @ $50.00	264,000.00
Excavation all in earth. 5 mi. (5) (5280ft) @ $7.00	184,800.00
Excavation in hardpan, ripping required, no lining. 5 mi. (5) (5280 ft) @ $12.00	316,800.00
Island Canal, 4 mi.	
Excavated in hardpan, ripping required, drops excavated in solid rock, no lining. 1 mi. 5280 ft. @ $2.50	13,200.00
Excavation all in earth, 3 mi. (3) (5280) @ $1.00	15,840.00
Beaver Creek conduit & siphon.	
5' x 1,500' steel low pressure conduit. 1,500 ft. @ $30.00	45,000.00
42" x 2,000' steel siphon, maximum 400' head, including rock excavation and anchorage. 2000 ft. @ $150.00	300,000.00
Transitions and blowoff.	6,000.00
Schoolie Flat forebay canal, 3½ mi.	
Excavated in hardpan, ripping required, no lining (3.5) (5280 ft.) @ $10.00	184,800.00
Schoolie Flat pumps, motors, installed, 2,780 hp	
2,780 h.p. @ $60.00	166,800.00
Pump discharge pipe.	
54" x 4000' @ $30.00	120,000.00
36" x 1000' @ $20.00	20,000.00
28" x 1000' @ $15.00	15,000.00
Ditch and lateral construction.	
Island 650 acres @ $125.00	81,250.00

Simnasho	
210 acres @ $100.00	21,000.00
Schoolie Flat	
5010 acres @ $100.00	501,000.00
Total Project Cost	$2,367,140.00
Cost per acre	
$2,367,140.00 ÷ 5870	$403.00 per acre

<u>11-13.28</u> <u>Feasibility.</u> Irrigation development from the upper Warm Springs River constitutes the greatest single irrigation potential of the reservation. Approximately 46% of the total class II acreage mapped on the reservation lies on Schoolie Flat. The per acre cost of $403.00 for irrigation development of land that is predominately class II, see Table 11-13.7A, is compared with the irrigation cost of the Tenino Unit having an estimated development cost of $301.00 per acre and containing acreage that is predominately class III. See paragraph 11-12.5 and 11-12.9.

<u>11-13.29</u> The estimated development cost of $403.00 per acre would prohibit the success of the unit based solely on an agriculture of forage crops. Justification of such an expenditure would require the cultivation of high value crops. From considerations based solely on monetary justification, the feasibility of construction may be questioned. There are, however, benefits of increased social and economic stability that would result from the construction of the unit. The irrigation of 5,000 acres of the most potentially productive lands on the reservation would have a far reaching effect upon the entire agricultural pattern of the reservation.

<u>11-13.30</u> There is also a benefit that would accrue to the Island and Schoolie Flat by the construction of the irrigation unit that is separate from the benefits derived solely from irrigation water. This is the availability of surface water for domestic purposes. Both of the regions lack adequate sources of ground water. Wells on Schoolie Flat or the Island must now be drilled to depths of 300 to 550 feet to secure but meager flows. Although there are no well failures from dry holes, the uncertainty of obtaining even moderate flows from a well that may cost over $3,000.00 to construct, has discouraged ground water development from wells. It will undoubtedly continue to do so.

<u>11-13.31</u> The construction of an irrigation system into either of these areas would be followed soon by extensive electrical distribution. The availability of sources of surface water and electrical utility service would solve the domestic water problem, as treatment of surface water could be provided through the use of automatic chlorinators. The type of automatic chemical disinfection equipment, its use and application for rural installations is described in section 10-6. Ponds, reservoirs and cisterns recharged from the irrigation canals could provide stock and domestic water throughout the year. Reservoirs

constructed using approved rolled earth construction, impermeable membranes, or soil additives could provide reservoirs tight enough to hold water during the time the irrigation system is shut down.

11-13.32 Water spreading during the summer months on the Island and on Schoolie Flat would undoubtedly contribute to well performance. This would probably have a greater effect on Schoolie Flat, where there are apparently numerous impermeable lenses which give rise to perched water. The continued recharge during the summer of these perched sources would be of great value to the improvement of ground water supplies. The benefits from improved well performance would probably not have great importance, as use of surface waters described in paragraph 11-13.31 would be possible.

11-13.33 Electricity for Pumping. The pumping plant at Schoolie Flat, requiring approximately 2,780 connected brake-horsepower, would appear to constitute one of the larger single blocks of potential electrical consumption on the reservation. The use of low cost electrical energy that has become available to the Confederated Tribes from previous negotiations would be advantageous at this site.

11-13.34 Coordination with Power Development. The possibility exists for a power site at the Beaver Creek siphon. The site would be served by a head slightly exceeding 400 feet. Two possible plans for development are (1) canal and conduit system providing simultaneous operation, and (2) canal and conduit system providing non-simultaneous operation. Each would require increased storage at the Schoolie Pasture site.

11-13.35 Without withdrawals for simultaneous irrigation the main canal, conduit, and the westerly portion of siphon would be designed for power demand. Without irrigation withdrawals the potential power at continuous operation would be approximately 4,500 brake-horsepower, or 40 percent of that reported by Helland (18) for power at the proposed Miller Flat site. Withdrawals for irrigation would reduce the yearly runoff available for power by approximately 44,000 acre-feet or 36 percent. Continuous power available at the site after irrigation withdrawals would be approximately 3,000 brake-horsepower.

11-13.36 Irrigation development and power development as described in 11-13.33 would not change power potential at the Hot Springs site. See Helland's report, Appendix XII-E.2.

11-13.37 It does not appear likely that a power site at the Beaver Creek crossing would be attractive to investment. Simultaneous operation of both irrigation and power facilities would require considerable increased cost of storage, open channel, conduit and west half of siphon. Non-simultaneous operation would require only the increased cost of storage, and the direct cost of the hydraulic and generating machinery. The reduction in total power due to irrigation withdrawals, and conflict in use of water would appear to present unfavorable attention to the site for power development under any method of joint use.

Section 11-14: Potential Irrigation from Upper Warm Springs River for Sidwalder Flat, Miller Flat, Dry Creek, and Schoolie Flat from Coordinated Power Development.

11-14.1 Description. Irrigation of Sidwalder Flat, Miller Flat, Dry Creek and Schoolie Flat could be possible from the power canal described in paragraph 12-5.3 and in Appendix XII-E.2. The general location of the power canal as it crosses Sidwalder Flat and Miller Flat is shown on the map Appendix XII-F. The canal would command much of the irrigable acreage of these two plateaus, and would be in a position to divert water into the drainage above Dry Creek. Water to serve irrigation on Schoolie Flat could be taken from the lower end of the penstock serving the Miller Flat power site. A high pressure conduit located on the south wall of Warm Springs canyon discharging by gravity at the approximate 2,525 foot contour near location 8/12-28A would provide water to a pumping forebay. The length of the high pressure conduit would be approximately 3,000 feet. The pump discharge pipe having a length of about 10,000 feet would discharge at the 2,800 feet contour near location 8/12-15H. No provision would be made for supplying irrigation water to the Island.

11-14.2 Irrigable Lands. Lands covered by the canal system are classified by the recent soil survey of the Bureau of Indian Affairs, Appendix XI-D.1 as follows:

Table 11-14.2A Land Classification Acreage within Unit.

Area	Class I	Class II	Class III	Class IV	Class VI	Class VII
Schoolie Flat	20.5	4,100.0	890.0	276.4	327.0	6,150.0
Miller Flat	--	484.9	--	--	9.8	2,265.5
Sidwalder Flat	4.2	1,564.9	500.4	470.7	744.3	6,305.5
Dry Creek	--	117.5	711.4	431.4	190.8	1,422.2
Simnasho	--	47.3	162.2			

TOTAL of Class I, II, and III: 8,603.3 acres

11-14.3 Lands considered irrigable are all the Class I, II, and III acreages. The feasibility of irrigation on Miller Flat appears very doubtful because of the small amount and dispersement of irrigable lands. The cost of constructing a lateral system to serve less than 500 acres dispersed throughout 2,700 acres would be high. The soil survey shows that much of the Class III land in the Dry Creek area lacks fertility, and would probably not respond well to irrigation. The two remaining areas to be served by this proposal are the Schoolie Flat and Sidwalder Flat area. Sidwalder Flat can be served by an expansion of existing Mill Creek Unit, whereby approximately 1,586 acres of the 2,070 mapped irrigable acres could be served with little additional construction cost for development of water source. The largest block of irrigable land is that on Schoolie Flat. The irrigation of the higher lands on Schoolie Flat by this plan would require a total pumping lift of about 325 feet, about 75 feet more than the plan described by section 11-13. A total of 7,017 acres in excess of the 1,586 acres served on Sidwalder Flat by regulated Mill Creek diversion, see section 11-11, would be irrigated by the unit.

11-14.4 Water Supply. The total regulated runoff from the Warm Springs River at Schoolie Pasture, less residual flow and canal losses would be available to the combined use of power and irrigation. Helland (18) estimated the regulated flow for 100% operating time at the Miller Flat power site to be 140 cubic feet per second. If a 25% canal loss occurs between the Schoolie Pasture reservoir and the Miller Flat power station, if 10 cubic feet per second residual flow is allowed below the Schoolie Pasture dam, and if the runoff ratio of 0.90 (see paragraph 11-13.11) is assumed, the disposition of water less that for irrigation from the power canal is anticipated to be:

Total annual runoff at Hehe gaging station	134,000 ac.-ft.
Total annual runoff at Schoolie Pasture (0.90) (134,000)	120,600 ac.-ft.
Canal loss between reservoir and Miller Flat power site (0.25) (120,600)	30,150 ac.-ft.
Net runoff to power site	90,450 ac.-ft.
Net discharge at power site, 100% operating time	125 cfs.

11-14.5 The estimate of 125 cubic feet per second continuous discharge at the Miller Flat power site is considerable less than estimated by Helland. Helland used in his estimate a continuous discharge of 130 cubic feet per second from the reservoir. An additional 10 cubic foot per second from Mill Creek and Badger Creek in his estimate provided 140 cubic foot per second continuous discharge at the power site. This would require considerably smaller canal losses than have been assumed throughout this discussion of potential irrigation construction on the reservation. For the purposes of a study of a coordinated program of hydro-electric and irrigation development from the Schoolie Pasture reservoir, Helland's estimate of water available to the power site will be used, 101,500 ac.-ft. annually.

11-14.6 It is assumed that the land irrigated from the power canal to be the 8,603 acres tabulated in Table 11-14.2A, less the 1,586 acres on Sidwalder Flat covered by the plan of section 11-11. (Assuming construction of plan of section 11-12.) A total of approximately 7,017 acres remain to be irrigated from water diverted from the Miller Flat power canal. With a 3.4 foot per acre farm application and 20% system loss, the anticipated irrigation demand from the power canal would be 30,000 acre-feet. This would have the effect of reducing the 140 cubic feet per second continuous discharge at the Miller Flat site of Helland's report to approximately 100 cubic feet per second, a 28.5% reduction. The continuous brake horsepower for regulated flow at the Miller Flat power site would be reduced from 11,200 to 8,000. The estimate tabulated in paragraph 12-5.16 shows diversion from the power canal for the entire Sidwalder Flat, while the estimate in this paragraph shows diversion for Sidwalder Flat not covered by regulated diversion from Mill Creek.

11-14.7 Power Canal, Conduits and Penstock. The capacity of the water conveyance system to satisfy the requirements of the power installation would depend upon the size of generating machinery installed. This selection would be governed by the type of electrical load to be carried. A peaking load would require the larger installed capacity, larger canals, conduits, penstocks, and possibly some provision for secondary storage near the power site. With such an installation the additional expense for water conveyance to be borne by irrigation would be smaller than if the power plants were designed to run more or less continuously. The capacity of power canal, conduit, and penstock to the power site would be required to be of a size adequate to handle both irrigation and power simultaneously. It is doubtful that a satisfactory operation of the power facilities could permit complete shutdown while irrigation demands used the power canal exclusively during the irrigation season.

11-14.8 Design Summary for Simultaneous Operation. To attempt a design summary or cost estimate of hydraulic conveyance items at this time is intended to serve only as a guide in comparing feasibilities with other comparable plans for irrigation. To obtain a basis of making a comparison of cost it is assumed that installed generating capacity at the Miller Flat site is based on 50% operating time for regulated flows computed by Helland. Unit costs for canal and conduit construction are as used in paragraph 11-13.27, extended in direct proportion for increased capacity.

Storage.
Rock and earth dam on Warm Springs River near outlet of Schoolie Pasture. Height 125 feet. 600 foot long. 2:1 slopes. 25 foot crown. 100,000 acre-feet.

Schoolie Pasture diversion.
At 2700 foot contour at 7/10-8F on right bank. Inlet capacity 450 cfs.

Power canal.
25 mile open channel. 25% loss. Canal terminates at pressure pipe 8/12-30D. Elevation 2600 feet above sea level. Terminating discharge at Sidwalder diversion 385 cfs. Terminating discharge at pressure pipe 350 cfs.

Sidwalder Flat diversion.
20 cfs. diversion to 476 acres not served by Mill Creek.

Miller Flat diversion.
15 cfs. diversion to 485 acres.

Dry Creek diversion at pressure pipe inlet.
25 cfs. diversion to 830 acres.

Pressure Pipe.
Inlet 8/12-30D, elevation 2600 feet above sea level.
Outlet 8/12-33B, elevation 2500 feet above sea level.

Length 14,000 feet. Capacity 300 cfs. Diameter 7'-6". Friction loss 20 feet. Manning's n = 0.013.

Penstock.
Discharge at 8/12-28K, elevation 1600 feet above sea level. Length 4000 feet. Capacity 325 cfs. Diameter 6'-0". Friction loss 20 feet. Manning's n = 0.013.

High Pressure conduit to Schoolie Flat.
High pressure conduit inlet 8/12-28K. Capacity 125 cfs. Length 3,000 feet. Discharge location 8/12-28A at 2525 feet above sea level. Diameter 4'-0". Friction loss 20 feet. Manning's n = 0.013.

Schoolie Flat pump site.
3800 hydraulic horsepower, 70% efficiency. Multiple units parallel connected. 48" x 6000' steel, 36" x 2000' steel, 28" x 2000' steel discharge.

Schoolie Flat distribution.
Ditch and lateral system to 5011 acres.
Diversion and waste to 210 acres at Simnasho.

11-14.9 Estimated Cost for Simultaneous Operation. An estimate of construction cost of the storage, canals, conduits, etc, is:

Schoolie Pasture dam.	
Embankment, rock and earth 300,000 yd.^{3} @ \$1.75	\$ 525,000.00
Spillway, diversion. 20% embankment	105,000.00
Fishway. 25% embankment	131,250.00
Power canal. 25 mi.	
Excavation in rock, sidehill, trapezoidal concrete lining, 1 mi. 5280 @ \$100.00 lin. ft.	528,000.00
Excavation in hardpan, ripping required, no lining. 12 mi. (5280)(12) @ \$25.00 lin. ft.	1,584,000.00
Excavation in earth, 12 mi. (5280)(12) @ \$15.00 lin. ft.	950,400.00
Pressure pipe. 7'-6" x 14,000'. 14,000 @ \$60.00	840,000.00
Penstock. 6'-0" x 4000'. 4,000 @ \$200.00	800,000.00
Sub-total	\$5,467,250.00

Pro-rate charge to irrigation.	
Dam, spillway, and fishway(ratio 30/101.5),1/ (0.296) ($761,250.00)	$ 225,330.00
Power canal (Ratio 185/385),2/ (0.480) ($3,062,400.00)	1,469,952.00
Pressure pipe and penstock(ratio 125/325),2/ (0.385) ($1,640,000.00)	631,400.00
High pressure pipe, 4'- 0" x 3000'. 3000 @ $100.00	300,000.00
Schoolie Flat pumps and motors, installed 3800 hp. 3800 @ $60.00	228,000.00
Pump discharge pipe.	
48" x 6000' @ $25.00	150,000.00
36" x 2000' @ $20.00	40,000.00
28" x 2000' @ $15.00	30,000.00
Ditch and lateral construction.	
Schoolie Flat. 5010 acres @ $100.00	501,000.00
Sidwalder Flat. 660 acres @ $125.00	82,500.00
Miller Flat. 485 acres @ $150.00	72,750.00
Dry Creek. 830 acres @ $150.00	124,500.00
Total Irrigation Costs	$3,855,432.00
Pro-rate Cost per acre $3,855,432.00 ÷ 7017	$549.00 per acre

11-14.10 Computed on a pro-rated basis as shown in 11-14.9 the combined irrigation and power development for simultaneous operation does not appear feasible. The increased cost for enlarged canal, conduit and penstock to provide irrigation simultaneously to power is prohibitive.

11-14.11 It would appear doubtful that a combined irrigation-power coordinated program permitting non-simultaneous operation only would be attractive to power development. If, however, such a plan would be feasible for power development, there is a great saving in initial construction cost due to reduction of required canal and conduit capacity. Assuming power demand of 200 cfs, see paragraph 11-14.6 and 11-14.8, the required capacity of the canal and conduit system is dependent upon power demand only. The water conveyance system from the dam to the power site would initially cost approximately 200/385 (52%) of that itemized in paragraph 11-14.9.

1/ Pro-rate ratio based on annual irrigation diversion/annual delivery to power site. See 11-14.5, 11-14.6, 11-14.8.

2/ Pro-rate ratio based on irrigation demand/total delivery capacity. Canal losses are excluded.

11-14.12 Estimate Cost for Non-Simultaneous Operation. The estimated construction cost for non-simultaneous operation is:

Dam, spillway and fishway. from 11-14.9	$ 761,250.00
Power canal, conduit and penstock, 1/. 52% of $4,706,000.00	2,447,120.00
Sub-total, water storage and conveyance to power site.	$3,208,370.00
Pro-rate charge to irrigation.	
Dam, spillway, fishway, power canal, conduit, and penstock. (ratio 30/101.5) 2/ (0.296) ($3,208,370.00)	$ 949,678.00
4' x 3000' pressure pipe, 3800 hp installed pumps and motors, 10,000' pump discharge pipe, ditch and lateral system to Schoolie Flat, Sidwalder Flat, Miller Flat, and Dry Creek. See 11-14-9	1,528,750.00
Total Irrigation Costs	$2,478,428.00
Pro-rate Cost per Acre $2,478,428.00 ÷ 7017.00	$353.00 per acre

11-14.13 Feasibility. Neither the plan for a coordinated power-irrigation development providing simultaneous operation of both irrigation and power, or a plan for non-simultaneous operation of irrigation and power appear to be feasible. The pro-rated irrigation construction cost of canal, conduit, and penstock permitting simultaneous operation is excessive. The pro-rated irrigation construction cost of non-simultaneous operation is favorable, but would probably be unacceptable from the standpoint of operation of power facilities. Water removed from the Upper Warm Springs for irrigation would constitute approximately 30% of the annual runoff. The remaining 70% of the runoff that would be available to power only during the period that the irrigation facilities are inoperative, does not appear attractive to power development.

1/ Based on 200 cfs power demand at Miller Flat power site. See 11-14.8 and 11-14.11.

2/ Pro-rate ratio based on annual irrigation diversion/annual delivery to power site.

11-14.14 At the present time it appears that the development as outlined in section 11-13 is the most favorable for irrigation of the large block of irrigable land in the northeast part of the reservation. The selection of the plan of section 11-13 precludes irrigation of either Miller Flat or Dry Creek.

Section 11-15: Summary.

11-15.1 History of Development. Preliminary investigations and surveys for irrigation development on the reservation began in 1910, and have continued intermittently to the present time. Actual construction began during 1936, when a Shitike diversion was built. Construction of the Mill Creek Unit began in 1937. Construction continued periodically at eight independent units within the project, six of these being in operation at the present time. Engineering for all units has been under the direction of personnel of the Bureau of Indian Affairs.

11-15.2 Justification for Irrigation. In a climate where the annual precipitation is approximately twelve inches, occuring mostly during the winter months, dry farming is not profitable. The need for irrigation to supplement the meager precipitation is further increased by the geology and topography found in the central and eastern part of the reservation. The present project was justified upon the recognized need to increase forage capacity on the reservation. Although it is assumed that the agricultural economy of the reservation will continue to be based primarily upon livestock and major consideration of the needs and requirements of irrigation is to be directed toward maintenance of forage resources, the economic feasibility of some of the potential irrigation development will require more extensive use than that from forage only.

11-15.3 Water Supply. Irrigation on the reservation is generally dependent upon the streams that rise in the Cascades and flow easterly across the reservation. The exceptions are the present Simnasho Unit, and the potential of irrigation by direct pumping from the Deschutes River. The streams of the reservation are remarkably sustained in discharge, and have a water quality favorable for irrigation supply. One major storage site exists on the reservation, a potential for approximately 100,000 acre-feet of storage at Schoolie Pasture. A small but vital storage potential also exists at the headwater lakes to Mill Creek. Available diversion for irrigation of Tenino Creek Valley and Simnasho Flat are at elevations requiring pumping. It is expected that irrigation works constructed upon the Dalles formation extending over much of the plateau lands of the reservation will cause heavy seepage losses. A procedure for water right allotment has not been established at the reservation.

11-15.4 Description of Existing Units. The entire Warm Springs Project is composed of eight small individual units, six now being in operation. There has been as much as 1,300 acres of assessed lands within the project. 1,286 acres are now being assessed, 25% to 50% of the assessed lands being actually irrigated annually. A tabular description appears in Table 11-15.4A.

Table 11-15.4A Existing and Former Units:

Name	Water Source	Assessed Acreage, 1959	Irrigated Acreage, 1959	O & M Cost. (SMCO est.)
Mill Creek	Mill Creek	842	272	$ 3.20
Simnasho	Quartz Creek	40	35	5.13
Shitike	Shitike Creek	70	27	13.20
Tenino	Tenino-Shitike	40	16	8.70
Middle Wm.Sp.=	Warm Springs River	206	87	10.62
Lower Wm. Sp.	-do.-	90	20 3/	7.40
Deschutes	Deschutes River 1/	---	---	------
Seekseequa	Seekseequa Creek 2/	---	---	------

1/ Formerly 33 acre pumping unit.

2/ Formerly 8 acre diversion unit. Inoperative due to short supply of water.

3/ Irrigated acreage for 1958 indicated here. Unit was inoperative during 1959 due to canal failure.

11-15.5 Operation of Existing Units. The canals and water control structures of the entire project are in a poorly maintained condition. Much of the original construction was of temporary construction, and has been gradually replaced. Operational problems have not been due to a shortage of water at the diversion point as much as due to inadequate ditch capacity and inadequate water control structures. There is a marked dissatisfaction of the water users towards the operation of the project, a general discouragement that has undoubtedly contributed to the but partial use of available facilities. Actual operation and maintenance costs have exceeded the assessed charges. Reimbursible funds due as liens against the project lands now exceed $300,000.00. The Tribes have requested that all liens be cancelled, and the rehabilitated project be turned over to the water users. The rehabilitation cost for the project is estimated by the Bureau of Indian Affairs to be approximately $20,000.00.

11-15.6 Irrigation Methods and Land Leveling. Much of the soils of the reservation are so shallow and lie upon such uneven terrain, that little flexibility of irrigation methods is available to the water user. Land leveling on the reservation has not been satisfactory, due to either improper gradient design, lack of supervision of grading operations, or improper irrigation methods. The use of sprinkler irrigation would be advantageous on the shallow soils having such uneven topography to prohibit economical leveling.

11-15.7 Irrigation without Joint Power Development. The tabulation below summarizes total potential irrigation development without a coordinated program for power generation.

Table 11-15.7A Irrigation Potential without Power Development.

Geographic Area	Water Source	Acreage	Remarks
Log Springs	Non-perennial water-ways.	250	Topography and geology favorable for small water-way holding dams.
Island	Warm Springs	650	Within unit serving Schoolie Flat and Simnasho.
Schoolie Flat	-do.-	5,011	-do.-
Simnasho	-do.-	209	-do.-
Sidwalder Flat	Mill Creek	1,586	Regulated diversion serves all but 484 of mapped irrigable acreage.
Deschutes Valley	Deschutes	250	Pump installations to gravity or sprinkler systems.
Lower Tenino and Shitike Valley	Shitike	500	70 acres gravity diversion to Shitike Valley, and 430 acres pumping to lower Tenino Valley.
Warm Springs Valley	Warm Springs	296	Present Middle and Lower Warm Springs Unit.
Seekeequa Valley 1/	Whitewater	250	Part of unregulated diversion from Whitewater River.
Tenino Bench and Dry Hollow 1/	-do.-	1,273	-do.-
Metolius Bench 1/	-do.-	1,435	-do.-
Total		11,710	
Total less irrigation from Whitewater diversion		8,752	

1/ Approximately 35 miles of main canal required to serve the combined unit of 2,958 acres, eight miles of the main canal being constructed in extremely rugged terrain. Unit does not appear feasible.

11-15.8 Irrigation with Joint Power Development. The tabulation below summarizes total potential irrigation development when constructed with a coordinated program of power generation.

Table 11-15.8A Irrigation Potential with Power Development.

Geographic Area	Water Source	Acreage	Remarks
Log Springs	Non-perennial water-ways.	250	Topography and geology favorable for small water-way holding dams.

Island	Warm Springs	650	Diversion serving Island only.
Schoolie Flat	-do.-	5,011	Served from outlet of Miller Flat site penstock.
Simnasho	-do.-	209	Tail water and runoff from Schoolie Flat
Sidwalder	Mill Creek and/ or Warm Springs	2,070	Diversion from Mill Creek to 1,586 acres with diversion from Miller Flat power canal to 484 acres if Mill Creek is not diverted to Metolius for power, irrigation of total Sidwalder acreage from Miller Flat power canal.
Miller Flat	Warm Springs	485	Diversion from Miller Flat power canal.
Dry Creek	-do.-	829	-do.-
Deschutes Valley	Deschutes	250	Pump installations to gravity or sprinkler systems.
Lower Tenino and Shitike Valley	Shitike	500	70 acres gravity diversion to Shitike Valley, and 430 acres pumping to lower Tenino Valley.
Warm Springs Valley	Warm Springs	296	Present Middle and Lower Warm Springs Unit.
Seekseequa Valley1/	Whitewater	250	Diversion from Tunnel power canal.
Tenino Bench and Dry Hollow 1/	-do.-	1,273	-do.-
Metolius Bench 1/	Whitewater	1,435	Diversion from Tunnel power canal.
Total.		13,508	
Total less irrigation from Tunnel power canal diversion		10,550	

1/ Diversion is from penstock inlet having static head of 1,300 feet. 25 miles of irrigation main canal will have heavy seepage losses in unlined channels. Power revenue loss due to irrigation diversion and cost of construction of main canal appears to prevent economic operation of irrigation diversion from power canal at this unit.

Section 11-16: Recommendations.

11-16.1 Stream Data. Irrigation development on the reservation, either with or without joint power development, requires additional knowledge of the stream runoff at the higher elevations. Data on Mill Creek are especially needed if Mill Creek is to be developed for irrigation only. Streams tributary to the Deschutes appear to have greater application to irrigation development or combined power-irrigation development than do the streams tributary to the Metolius drainage. Additional stream measurements near proposed diversion points of either Mill Creek, Shitike Creek, Warm Springs River, or other minor streams should be conducted simultaneously with measurements at the former continuous gaging stations on Shitike Creek and Warm Springs River to provide a basis of projecting existing data. Also see 6-5.1.

11-16.2 Storage. Effective development of Mill Creek for irrigating Sidwalder Flat requires the maximum economical storage at the headwater lakes. The hydrology and topography of the headwater lake area should be further investigated to determine the true potential of irrigation from a regulated Mill Creek diversion to Sidwalder Flat. Storage at Schoolie Pasture is required for irrigation from the Warm Springs river, either with or without joint power development. Additional geologic information regarding conditions at the dam site and at the reservoir is required for the design of either plan.

11-16.3 Water Rights. Although apportionment of surface or ground waters for use by irrigation, domestic, or stock has apparently not been a problem on the reservation in the past, it is suggested that a code for the uniform determination of water rights be established. As available sources of water on the reservation become more fully used, problems of apportionment will become increasingly complex. Without a code for water right allotment, satisfactory solutions to these problems may soon become impossible. The most opportune time for establishment of such a code is now, before extensive infringements occur.

11-16.4 Operation of Existing Project. The satisfactory operation of the existing project requires the rehabilitation of the individual units to a state of repair and maintenance permitting approved standards of performance. Irrigation methods on the reservation will not improve if the project remains in its present condition. It is suggested that upon rehabilitation of the present project, the project be vigorously maintained at the optimum standard of performance. This will require establishing a program of systematic maintenance and repair. The direction for all operation, maintenance, repair, and construction should be under the direct supervision and responsibility of an engineer having the ability and interest to perform his professional duties and to create confidence and interest of the water users.

11-16.5 Operation Budget and Charges. The required funds to defray actual annual costs of operation, maintenance, and repair exceed the existing annual assessed charges. It is suggested that annual assessed charges be increased to be consistent with the actual costs of operating the project maintained to satisfactory standards of performance. Lands now assessed, but incapable of being irrigated due to either construction or operation of the project, should be removed from the assessed rolls.

11-16.6 Reimbursible Funds. Operation, maintenance, and repair charges in excess of $300,000.00 now exist as liens against the approximately 1,300 acres of assessed land on the project. The conclusion and recommendation made by the Bureau of Indian Affairs that all irrigation liens be cancelled and suspended is herein concurred. It is recommended that the Bureau turn the project over to the water users, the Tribes assuming responsibility for operation, at a time when a well defined policy of administration and operation of the project be determined, and its continued satisfactory performance can be assured.

11-16.7 Irrigation Counsel. Evidence points to a genuine desire of the water users to improve their ability to utilize the irrigation facilities with greater effectiveness. It is suggested that engineering personnel associated with the irrigation project provide increased advice and guidance to the water users. Counsel on all technical problems relating to use of water should be freely and expertly given, in a manner to stimulate interest and confidence of the water user, and to encourage effective use of the project.

11-16.8 Irrigation Methods. The shallow and uneven soils of the reservation require irrigation methods allowing a minimum of land leveling. Irrigation of forage crops by contour checks has a wide application on the reservation where topographic and soil conditions limit permissible land leveling. Light and frequent irrigations are suggested on the permeable soils of the reservation. Such conditions require moderate to large irrigating heads to permit water application in as short of time as possible. This also requires short field runs of water, if deep percolation is to be minimized at the upper end of the checks, borders, or furrows. Sprinkler irrigation on the light soils lying in uneven topography, and at the small irrigable tracts isolated from gravity irrigating systems is suggested.

11-16.9 Potential Irrigation from Mill Creek. If a program of hydro-electric development is found to be uneconomical on the reservation, surface water from Mill Creek can be most profitably diverted for irrigation to Sidwalder Flat. Regulation by storage at the headwater lakes is suggested. It is estimated that regulation of Mill Creek will allow application of water to approximately 77% of the total mapped land on Sidwalder Flat suitable for irrigation. A plan for power development at the Tunnel power site would divert waters from the upper Mill Creek to the Metolius drainage. Irrigation of Sidwalder Flat would then be dependent upon release from the Mill Creek power canal during the irrigating season, or diversion from the Miller Flat power canal. Regardless of the occasion for construction of either the Miller Flat power canal, or the Tunnel power site, or both, irrigation water should not be denied to the lands of Sidwalder Flat.

11-16.10 Potential Irrigation from Warm Springs River. The Warm Springs River offers the greatest irrigation potential of all the streams on the reservation. From a standpoint of irrigation, there appears to be an advantage for a joint use of hydraulic structures by irrigation and power development. The pro-rated initial cost chargeable to irrigation, based on proportionate water consumption, would be less than would the initial cost of hydraulic structures constructed solely for irrigation. An added benefit would be the service to additional lands, Miller Flat and Dry Hollow. The Island would not be served from diversion from the power canal. Although joint construction does not appear attractive from considerations of power generation, the decided advantage to irrigation from such a design, warrants further and complete investigation before extensive additional irrigation construction is undertaken on the reservation.

11-16.11 Potential Irrigation from Tunnel Power Canal. Diversion of water for irrigation from the Tunnel power canal does not appear feasible. Heavy anticipated canal seepage losses as the diversion canal traverses the Dalles soils of the Tenino and Metolius Benches, with the resulting excessive power revenue loss suffered by diversion from a high head power site, contribute to unfavorable economy of a combined power and irrigation installation. Rate of monetary return for water diverted into the Tunnel penstock for power generation would probably exceed that obtained by diversion into an irrigation canal to either Metolius or Tenino Bench. If power is not developed on the Metolius drainage, it is doubtful that the returns from irrigation alone could bear the cost of the entire diversion structure.

CHAPTER XII

HYDRO-ELECTRIC DEVELOPMENT

The Deschutes and Metolius Rivers, flowing in deeply cut canyons along the southerly and easterly boundaries of the reservation, have long been recognized for their excellent power potential. The streams flowing within the reservation have considerable value as sources of power. Development of these streams can be coordinated with irrigation development to serve areas now deficient in irrigation water.

Section 12-1: Previous Hydro-Electric Investigations,

12-1.1 Russell. One of the first investigations of water resources of the region was conducted by Israel C. Russell (52) during the summer of 1903. The field work was authorized under the joint auspices of the western section of hydrology and division of geology and paleontology of the U. S. Geological Survey. The report, appeared in the U. S. Geological Survey Bulletin no.252. While Russell's main purpose for conducting his field survey was reportedly to indicate where artesian water could be secured (52, p.11), observations he recorded were later used by investigators more specifically concerned with water power development.

12-1.2 Hincks. W. H. Hincks during the years 1911 and 1912 was employed to investigate irrigation and hydro-electric development on reservation lands. The work done by Hincks appears to have been the first study given to water power development on streams originating within the reservation. His work in evaluating the power potential was handicapped by the small amount of stream run-off records then in existence. The report of his findings was later incorporated into an investigation conducted in 1944 by R. C. Helland, (19). Copies of Hincks' preliminary investigation and recommendations are reportedly in U. S. Department of Interior files in Seattle, Washington.

12-1.3 Henshaw, McCaustland, and Lewis. The first detailed study of the hydro-electric potential of the entire Deschutes River and streams tributary to it appears to be that reported by F. F. Henshaw and E. J. McCaustland in cooperation with the office of John H. Lewis, Oregon State Engineer (22). The results of the study appeared in 1914 in the U. S. Geological Survey Water-Supply Paper no.344. The paper describes power sites and suggested impounding structure at each site for full development of the watershed. Although the entire course of the Deschutes, together with its two major tributaries, the Metolius and Crooked Rivers, was discussed in the report, there appeared no suggestion for water power development of those streams flowing through the reservation. This outline for hydro-electric development on the Deschutes and Metolius Rivers was reviewed in a report to the Federal Power Commission in 1922 (84).

12-1.4 Williams. In 1924 Ira A. Williams (87), consulting geologist of Portland, Oregon, examined several dam sites on the Metolius River below its confluence with the Deschutes Rivers for the Columbia Power Company.

12-1.5 Stearns. During the summer of 1925, Harold T. Stearns (53) investigated the dam sites on the Crooked River from its mouth to Trail Crossing. Part of this study was devoted to a reconnaissance of the Deschutes River. A report appeared in 1931 in the U. S. Geological Survey Water-Supply Paper no. 637-D.

12-1.6 Helland. During the summer of 1944 R. O. Helland (18,19) of the U. S. Geological Survey investigated power development on streams flowing through the reservation. His report was somewhat a review and comment on the investigation conducted by Hincks thirty-two years earlier. Helland devoted four days to his field investigation. During the years that had followed the time of Hincks' work on the reservation, the entire area had been covered by quadrangle maps. Additional stream discharge records had been obtained. The report submitted by Helland was intended as preliminary information only, and had not been intended for release. Through courtesy of the Portland Branch of the U. S. Geological Survey, Portland Branch, the entire text of Helland's report appears in Appendix XII-E.

12-1.7 Private Utilities. The extent of investigation conducted by private electric utilities is not discussed in this report. That the magnitude of such investigations is extensive is evidenced by the fact that one utility, Portland General Electric Company, which now has in operation the arch dam at the Pelton site, has submitted an application for construction of a rock-fill dam at the Metolius Site (Round Butte), and in its application for construction of the Round Butte dam makes reference to development of the Jefferson Creek Site on the Metolius River (48, Exhibit H). The current development of the Deschutes River by Portland General Electric follows in general the plan outlined by the Henshaw, and others, reported in Water-Supply Paper no. 344.

Section 12-2: Power Site Withdrawals.

12-2.1 Development of Policy. Following two messages to Congress by President Theodore Roosevelt in April, 1908, and January, 1909, public interest was for the first time focused on the disposition of water powers of lands in the United States. By President Roosevelt's action, special acts conferring franchises for development of water power were vetoed. His veto was prompted by the belief that adequate provision for the protection of the interests of the general public had not been incorporated into the franchises.

12-2.2 W. B. Heroy describes the developments following President Roosevelt's veto (22, p.168):

> "While this question of legislative policy was being discussed, administrative action for the purpose of preventing the alienation of water power was in progress. The Reclamation Service, under instructions from Secretary Garfield, recommended for his approval withdrawals affecting approximately 3,500,000 acres along western rivers in the period from December 4, 1908

to February 27, 1909. These withdrawals had their legal basis in part in the general powers of the Secretary of the Interior as the supervisor of the public lands, and in part in the authority conferred by the reclamation act (act of June 17, 1902, 32 Stat., 388) to withhold from disposition in the period from March to August 1908 similarly recommended the withdrawal as administrative sites of a large number of small tracts within or near national forests, which were believed to occupy strategic positions with relation to future power development. The purpose of these administrative sites as regards power was not, however, generally apparent until after March 2, 1909, when Secretary Garfield recommended their withdrawals from all entry except under the right-of-way acts, thus specifically holding them for use in connection with irrigation and power development......"

"His successor, Secretary Ballinger, undertook almost immediately the consideration of the water power situation and directed his attention to the advisability of retaining in force the first form and administrative withdrawals approved by Secretary Garfield. Fearing as a result of his investigation that the withdrawals rested on no secure statutory foundation, he directed their revocation, with the result that in April 1909, nearly all the withdrawn lands were restored to entry. Strong opposition to this action developed almost immediately, however, with the result that it was reconsidered. On April 23, 1909, after a conference between the Secretary, the Director of the Reclamation Service, and the Director of the Geological Survey, the latter was directed to make an investigation of water power sites on the public domain outside of national forests, which were not included within withdrawals for reclamation projects, with a view to securing at the next session of Congress legislation to control and regulate their disposition. Investigations were immediately undertaken by the Geological Survey along the lines directed, and as a result large areas of public lands controlling streams valuable for power development were promptly withdrawn. These withdrawals were styled as 'temporary power site withdrawals,' and were in terms in aid of legislation........."

12-2.3 Temporary Power Site Reserve No.66. The first of these withdrawals in the Deschutes River basin directly applying to lands within the reservation was the Temporary Power Site Reserve No. 66, an action approved December 30, 1909. A copy of the withdrawal order appears in Appendix XII-C.1.

12-2.4 Power Site Reserve No. 66. During the next session of Congress consideration was given to the entire subject of withdrawals of public land. As a result a general act approved June 25, 1910 (36 Stat., 847) authorized the President to make such withdrawals. A special act (36 Stat., 855) was then passed on the same day authorizing the Secretary of the Interior to withdraw water power sites on Indian reservations.

12-2.5 Almost immediately after the passage of the general withdrawal act the President confirmed all outstanding temporary withdrawals. The provisions of the Temporary Power Site Reserve No. 66 were confirmed as the Power Site Reserve No. 66 on July 2, 1910, subject to the provisions of the withdrawal act of June 25, 1910 (36 Stat., 847). A map showing general location of lands withdrawn by this order appears in Appendix XII-A.

12-2.6 Indian Lands Reserve No. 2. A withdrawal of the lands along the Deschutes and Metolius Rivers in the Warm Springs Indian Reservation which appeared to be valuable for power development was made in accordance with the provisions of the special withdrawal act relating to Indian reservations (act of June 25, 1910, 36 Stat., 855, 858) on November 1, 1910. A copy of the withdrawal order appears in Appendix XII-C.2.

12-2.7 Power Site Modification No. 26. By an order approved October 8, 1912, Power Site Reserve No. 66 was modified by Power Site Modification No. 26. The order applied to lands adjacent to the Metolius River in Township 10 South, Range 10 East. The order affecting approximately 1,300 acres of land was made to conform previously unsurveyed land to the official survey accepted in June 25, 1912. A copy of the modification order appears in Appendix XII-C.3.

12-2.8 Power Site Reserve No. 294. By an order approved October 8, 1912, Power Site Reserve No. 294 withdrew for water power sites lands involving approximately 62,000 acres lying within the Warm Springs Indian Reservation and being generally adjacent to the Deschutes, Metolius, and Warm Springs Rivers, and adjacent to Beaver, Mill and Shitike Creeks, and Whitewater River. Much of this land at this time was unsurveyed, and was described as being all lands within one-half mile of specified waterways. Lands in the easterly portion of the reservation having been previously surveyed were described by their subdivision. A copy of the withdrawal order appears in Appendix XII-C.4.

12-2.9 Power Site Interpretation No. 17. By an order approved April 29, 1922, Power Site Reserve No. 294 was modified to conform to Power Site Interpretation No. 17. The order applied to lands lying within Township 8 South, Range 10 East. The area previously recorded as withdrawn in the township as 9,600 acres was later reported in the official subdivision survey to be 7,512 acres. A copy of the interpretation order appears in Appendix XII-C.5.

12-2.10 Power Site Interpretation No. 30. By an order approved September 2, 1922, Indian Lands Power Site Reserve No. 2 was modified to conform to Power Site Interpretation No. 30. The order applied to lands lying throughout those described in the original order of November 1, 1910. The area previously recorded withdrawn as being 12,534 acres was later reported in the official subdivision survey to be 12,047 acres. A copy of the interpretation order appears in Appendix XII-C.6.

12-2.11 Other Withdrawals. Withdrawal actions of Federal Power Commission are tabulated:

Date	Number of Action	Location
October 14, 1925	F. P. C. Project #57	T. 7S., R. 9E.
-do-	-do-	T. 7S., R.10E.
-do-	-do-	T. 7S., R.11E.
-do-	-do-	T. 8S., R.11E.
-do-	-do-	T. 9S., R.11E.
-do-	-do-	T.11S., R.11E.
-do-	-do-	T. 9S., R.12E.
-do-	-do-	T.10S., R.12E.
-do-	-do-	T.11S., R.12E.
-do-	-do-	T. 9S., R.13E.
-do-	-do-	T. 6S., R.14E.
-do-	-do-	T. 7S., R.14E.
-do-	-do-	T. 8S., R.14E.
-do-	-do-	T. 9S., R.14E.
February 9, 1927	F. P. C. Project #57 (revision Section 6)	T. 9S., R.12E.
April 9, 1951	F. P. C. Project #2030	T. 9S., R.12E.
-do-	-do-	T.10S., R.12E.
June 28, 1957	F. P. C. Project #2030(rev)	T.10S., R.12E.
-do-	-do-	T.11S., R.12E.

12-2.12 Tabular Summary. A tabular summary of withdrawals by location appears in Appendix XII-B. Acknowledgement is made to the personnel of the U. S. Geological Survey, Portland Branch, for their cooperation offered in examination of office files.

Section 12-3: Water Supply.

12-3.1 Magnitude of Discharge. A tabulation of discharge records of streams bounding and flowing through the reservation appears in appendices of Chapter VI. Discharge for the Metolius and Deschutes Rivers at gaging stations adjacent to the reservation is tabulated as average monthly rates. Discharge for streams flowing within the reservation is tabulated as monthly run-off by each month for each year during which records were taken. The Warm Springs River is the largest stream flowing through the reservation. Whitewater River and Shitike Creek each display an annual run-off of about 75,000 acre-feet and having about 25% that of the Warm Springs River.

12-3.2 Steadiness of Flow. The rivers and streams bounding and flowing through the reservation have a steadiness of flow during the year that is favorable for water-power development. The Metolius and Deschutes Rivers display a sustained flow that is exceptional. While streams flowing through the reservation are not as uniform in discharge as the Deschutes and Metolius, they do discharge in sufficient magnitude and steadiness to make them valuable as sources of power.

12-3.3 Gradient. The Metolius and Deschutes flow in deeply cut canyons at a relatively flat gradient. The streams flowing within the reservation are characteristic of a comparatively steep and unbroken gradient. These streams, the Warm Springs River, Whitewater River, Mill Creek, Shitike Creek, and others have their headwaters on upland plateaus. The head waters flow into eroded water ways, which soon develop into deeply cut canyons in the lower reaches of the streams.

12-3.4 Topography. The topography and geology of the Metolius and Deschutes Rivers permit proximate sites for full development. These rivers, flowing in deeply eroded stream beds, permit economic impounding structures which confine flooded areas generally to untillable lands.

12-3.5 The unbroken and steep gradient of the streams flowing across the reservation suggests development utilizing headwaters diversion into canals or conduits. Stream diversion at the uplands into canals following closely the contour would develop head for power sites located in the adjacent canyon floor. The power canals could serve a dual purpose, as they would traverse or terminate at areas now in need of irrigation water.

12-3.6 Water Temperature. Another condition that favors the Deschutes River and its tributaries as water power sites is the freedom from drift and suspended matter. Streams flowing across the reservation are subject to ice during periodic cold winter periods. Water temperature readings of the Warm Springs River at Hehe Mill, see Appendix VI-I, during the years 1950-51 show a minimum water temperature for any time during this period to be 36°F. The Warm Springs River, being the largest of the streams within the reservation, may be expected to have minimum temperatures slightly exceeding that of the smaller streams. Temperature data of other streams flowing on the reservation are not available.

12-3.7 Data from Gaging Stations. Comparatively continuous run-off records have been maintained for gaging stations on the Metolius and Deschutes Rivers for the past fifty years. Gaging stations on streams within the reservation have been maintained periodically at different locations during this time. Discharge data for these streams are for stations considerably downstream from suggested stream diversion points.

12-3.8 The Warm Springs River, Whitewater River, Mill Creek, Shitike Creek and others are subject to effluent flow, gaining in discharge at dowstream stations. On the basis of observations taken simultaneously at two different stations on the Warm Springs River during four months of 1915, Helland, in the report appearing in Appendix XII-E.2, attempted to determine the effluent ratio of this stream. Such extension of meager run-off data can serve but little more than a basis for reconnaissance. Since the time of Helland's report in 1944, there have been little additional stream flow data obtained of these streams. Sufficient stream discharge data to accurately determine run-off at potentially favorable diversion points do not now exist.

12-3.9 Data for streams flowing across the reservation into the Metolius water shed consists solely of run-off measurements of three years duration of Whitewater River near its mouth. These measurements, shown in Appendix VI-F, appear to be generally consistent with measurements taken simultaneously at other gaging stations on the reservation. No data exist for discharge of Jefferson Creek. As run-off of the upper reaches of both Whitewater River and Jefferson Creek would contribute a large portion to the total power potential of streams within the reservation, a water-utilization study of streams flowing on the reservation is severely limited.

Section 12-4: Development of Rivers Bounding the Reservation.

12-4.1 Present Development. At the present time, one power site is developed on the Deschutes River. This is the Pelton dam and its re-regulating dam. The site, developed by Portland General Electric Company is briefly described in Appendix XII-D. Simtustus Lake, having an area of 540 acres, has proved to be a favored recreational spot of north central Oregon. An asset which has resulted from construction of Pelton Dam is the franchise enjoyed by the residents of the reservation to issue fishing permits at the reservoir.

12-4.2 Proposed Development. The proposed Round Butte dam is summarized in Appendix XII-D. Construction of this dam is proposed by Portland General Electric Company to be near the head of Lake Simtustus. This development is to be larger in all respects than the existing Pelton dam immediately downstream.

12-4.3 Undeveloped Sites. In a report appearing in U. S. Geological Water-Supply Paper no.344, Henshaw, Lewis, and McCaustland reported in detail potential water power sites on the Deschutes and its two major tributaries. Portions from this report appear in Appendix XII-D. Eight sites are described as being adjacent to the reservation, or having impounded waters adjacent to the reservation. A map appearing in Appendix XII-F shows the location of suggested sites.

12-4.4 The location of the existing Pelton dam and the proposed Round Butte dam are proximate to the sites described in the Water-Supply Paper no.344. The installations existing at Pelton dam and those proposed at Round Butte are considerably larger in size than those outlined in the aforementioned report, being designed to operate as sources of peak power.

12-4.5 Undeveloped sites on the Metolius River listed by U. S. Geological Supply - Paper no.344 are the Riggs site, Whitewater site and Jefferson Creek site. See Appendices XII-D and XII-F. In an application submitted by Portland General Electric Company (48, sh.1) for construction of Round Butte dam, development of the site immediately upstream on the Metolius is briefly outlined. This development would require diversion of the river into a canal at the Jefferson Creek site. The power canal terminating at a power station near the headwaters of the Round Butte reservoir would pass by the Whitewater site and Riggs site.

12-4.6 The Portland General Electric Company is the only organization, public or private, actively engaged in construction of water power development in this area. At this time the firm publicly claims no interest in further development of water power sites in this area. That this attitude will be of long duration, or is real, appears unlikely. Electric power consumption in the Pacific Northwest is constantly increasing. At the same time the number of undeveloped power sites is decreasing. It would appear that any hesitancy to continue development in an area once entered is only transitory, and would again continue after completion of any current construction project, namely Round Butte dam.

12-4.7 Benefits to be Derived. Any benefits to accrue to residents of the reservation upon development of power sites on the Metolius or Deschutes Rivers would appear to be limited to those relating to compensation for easement, and to recreation. It is unlikely that power development on these rivers would result in any significant industrial growth in the immediate area of the reservation, as overland transportation costs of materials would exceed the cost of transmission of electrical energy to present industrial regions.

Section 12-5: Development of Streams within the Reservation.

12-5.1 Present Development. There is at the present time no water power development on the reservation. At one time a diversion a few miles west of the Agency on Shitike Creek carried water to a small electric plant that supplied power to the Agency. This plant was dismantled when utility electric service became available.

12-5.2 Studies by Hincks and Helland. A brief description of studies conducted by Hincks and by Helland appears in paragraphs 12-1.2 and 12-1.6. These studies appear to have been the only studies made for evaluating the hydro-electric potential within the reservation. The report by Helland is submitted in full in Appendix XII-E.2. Suggested development as reported by Helland requires two separate water system units. The north unit consists of two power sites located on the Warm Springs River. The south unit consists of diversions from Jefferson Creek, Whitewater River, Mill Creek, Boulder Creek, and Shitike Creek which deliver water to three power sites. These units are shown on the map of Appendix XII-F. A brief summary of the undeveloped sites on the reservation follows.

12-5.3 North Unit. A proposed dam near the Schoolie Pasture Ranger Station would impound about 100,000 acre-feet of water behind a dam of 125 feet in height. Storage in this reservoir would be about 75% of the total annual flow of the river at this point. An open canal or conduit would follow the contour south of the river, picking up residual run-off from Badger Creek and Mill Creek as it proceeded southerly across Mill Creek Flat. The canal entering Miller Flat would discharge into a pressure conduit near the head of Dry Creek. The pressure conduit would terminate at a power site on the Warm Springs River near the headwaters of a diversion dam, the diversion dam being about 2 miles upstream from Hot Springs. This dam, being about 70 feet in height impounding about 25,000 acre-feet of water, would divert water into a canal flowing south of the river. A tunnel of about 1,200 feet length would be required. This water would be received by a power site on the Warm Springs River near its confluence with the Deschutes River.

12-5.4 South Unit. The south unit would divert waters from the upper reaches of Mill Creek, Boulder Creek, and Shitike Creek into the Metolius drainage that would otherwise flow towards the Warm Springs or Deschutes Rivers. Diversion of the upper reaches of Mill Creek and Boulder Creek into a canal would terminate at a power site on the Shitike Creek near North Butte. Tailrace water and diversion from Shitike Creek would be diverted around the west side of Shitike Butte. This water would be joined by tail waters from a power site supplied by diversions from the upper reaches of the Whitewater River and Jefferson Creek. The combined flow of these tail waters would flow along the north side of the Whitewater River, terminating at a power site located on the Whitewater River about one mile above its mouth. The development of the south unit would require drilling about 13,500 feet of tunnel conduit.

12-5.5 Generating Capacity. Helland summarizes the effective power potential from both units as being about 34,000 brake horsepower at 100% turbine operating time. This is considerably below the estimate 73,000 brake horsepower submitted 32 years earlier by Hincks. Both estimates have been reduced to 70% turbine efficiency. Discharge records available to Helland after Hincks report accounted for the downward revision of power estimates.

12-5.6 Since the time of Helland's report in 1944 run-off measurements for years 1949 to 1954 have become available for discharge of the Warm Springs River at the Hehe Mill. These records would appear to revise Helland's estimate of power from the Miller Flat site slightly upward. The only records available to Helland for this gaging station were those of four months during the year of 1915, and were of unusually small discharge. See Appendix VI-A. Any upward revision due to addition of these measurements would effect only capacity of the Miller Flat site, and would appear unsignificant in this reconnaissance report.

12-5.7 There have been no other run-off records made available since 1944 applying to other streams of the reservation that would alter Helland's conclusions regarding generating capacity.

12-5.8 Coordination with Irrigation Development. Both Hincks' and Helland's reports present the possibility for use of water diverted from power canals for irrigation use. Requirements of water development and irrigation may be served from the same canals to a large extent without any material change in the plan of development as outlined for power only. Power sacrificed by diverting water from the power canal into irrigation headworks would be limited generally only to that amount of water actually diverted. Power canal losses through seepage or evaporation would generally remain independent from that amount of water diverted for irrigation. From an overall consideration of conservation of surface water on the reservation, and minimizing of total initial costs and operating costs, the joint use of a single primary canal by both irrigation and power would be desirable.

12-5.9 Irrigation from North Power Unit. This north canal as it flows southeasterly across Mill Creek Flat and Miller Flat would command these areas which are now deficient in irrigation water. The canal, terminating at a pressure conduit near the head of Dry Creek, could supply irrigation water to irrigable lands on the valley floor of Dry Creek. See section 11-9.

12-5.10 Water diverted from this canal would be diverted from a power site having an operating head of 1000 feet. Assuming overall efficiency of 70%, this would mean that for each acre-foot of water diverted from the Miller Flat power canal for irrigation, approximately 720 kilowatt-hours of electrical energy would be sacrificed. Assuming electrical energy value as three mills per kilowatt hour, the monetary sacrifice for diverting an acre-foot of water from the Miller Flat power canal would be slightly more than two dollars.

12-5.11 Irrigation from South Power Unit. The proposed power canal terminating on the Metolius Bench at the Tunnel site could supply irrigation water to the easterly portion of the Metolius Bench, Tenino Bench, Dry Hollow and Seekseequa Valley. The power canal for this unit is not as favorably located for coordination with irrigation development as is the power canal described in paragraph 12-5.9. No point on the Tunnel site power canal would appear to be closer than 10 miles from irrigable lands.

12-5.12 Water diverted from this canal would be diverted from a power site having an operating head of 1300 feet. Assuming overall efficiency of 70%, this would mean that for each acre-foot of water diverted from the Tunnel power canal for irrigation, that approximately 940 kilowatt-hours of electrical energy would be sacrificed. Assuming electrical energy value as three mills per kilowatt-hour, the monetary sacrifice for diverting an acre-foot of water from the Tunnel power canal would be slightly less than three dollars.

12-5.13 Power vs. Irrigation. Both power and irrigation developments would have a common interest in locating main supply canals or conduits on the bench lands. Although it would appear that the value of the streams within the reservation have more value as sources of power than they do for irrigation, this does not mean that they have more value solely for power than for combined power and irrigation. Total annual run-off for these streams exceeds that needed for any anticipated irrigation development on the reservation. The sustained flow of these streams appears adequate to satisfactorily serve both needs. The conflict to joint operation would occur only during summer months when demands upon water by irrigation would divert water from power sites.

12-5.14 The greatest demand for irrigation water could be that diverted from the Miller Flat canal. Total irrigable (Class I, II, and III) acreage of Schoolie Flat, Sidwalder Flat, Miller Flat, and Dry Creek as determined by the recent soil survey is approximately 8000 acres. Assuming a farm application of 3.4 feet of water and losses from irrigation conveyance system as 20%, the ultimate annual diversion of water from the Miller Flat site would be approximately 34,000 acre-feet. The diversion of this quantity of water would reduce by about 47 cubic feet per second the continuous regulated flow to the Miller Creek site. The computed loss in power generating revenue per acre-foot applied to the farm if irrigation canal losses are 20% is $2.70. This is expensive water and would be prohibitive on the poorer soils. It would also require efficient irrigation methods. Assuming 40% of this diverted water returns to the Hot Springs reservoir the continuous regulated flow into the Hot Springs site would be reduced by about 40 second-feet. The total regulated potential from these two sites operating continuously at 70% efficiency would be reduced from 17,600 to 12,700 brake horsepower.

12-5.15 It would appear that the ultimate irrigable acreage on the Metolius Bench would never exceed 1400 acres. See Appendix XI-D.1. Because of the length of the diversion from the power canal and high permeability of the soil mantle in this area the maximum duty of irrigation water at the diversion may be expected to approach six acre-feet per acre. The ultimate annual requirement of irrigation would be 8,400 acre-feet. (Based on irrigation to Metolius Bench only. See 11-9.21 and 11-9.23.) The diversion of this quantity of water from the Tunnel site would reduce by about 12 second feet the continuous flow to the Tunnel site. The potential of the Tunnel site operating continuously at 70% efficiency would be reduced from 9,900 to 8,500 brake horsepower. Irrigation water diverted from the Tunnel site penstock would result in excessive power revenue. Irrigation canal losses on the bench soils are assumed to be 50%. This would mean each acre-foot applied to at the farm would mean a sacrifice of $5.50 in power revenue.

12-5.16 An adjusted summary of potential power and irrigation based on continuous operation is shown.

Power Site	Irrigation Diversion	Flow, cfs	B.H.P. (70% Eff.)
Miller Flat	--	93	7,300
Hot Springs	--	210	5,400
Trout Lake	--	25	1,600
Mt. Jefferson	--	40	5,500
Tunnel	--	83	8,500
--	Miller Flat Div. 1/	47	---
1	Tunnel Div. 1/	12	---
		TOTAL	28,300

1/ Based on 34,000 acre-feet and 8,400 acre-feet irrigation diversion at Miller Flat site and Tunnel site.

12-5.17 Development Costs. No development costs are available for the plan as outlined. A major item in the cost of the hydraulic structures would be that of the canal and conduit systems. Only two impounding structures, the Schoolie Pasture and the Hot springs dam, would be necessary other than minor diversion structures. The canal system would require about two and one-half miles of tunnel excavation, and a minimum of seven miles of pressure pipe. Canal or conduit construction in areas of rocky and rough terrain would be costly.

12-5.18 The impounding structures on the Warm Springs River at Schoolie Pasture and Hot Springs would require provision for the passage of migrant fish. These two structures being approximately 125 feet and

70 feet in height, respectively, would be located downstream from spawning beds. The diversion structures for the south unit would be sufficiently upstream or be of such low height as to require but rudimentary fishways.

12-5.19 The canals, tunnels, and conduits as outlined would constitute a major cost for the hydro-electric development as outlined. These structures would be located almost in entirety on topography of the Cascan or Dalles formations, materials often having a high permeability. Canal construction from the lava rock of the formation would be costly. It is anticipated that seepage loss from unlined open canals would be high, probably as high as 30 percent. Reduction of seepage loss would require canal lining, or application of a sealer material such as bentonite. Topography of the terrain is rugged, particularly along the proposed canal location of the south unit. In this unit, which contains over 90 percent of the proposed tunnel work, construction cost for hydraulic transmission structures will be costly.

12-5.20 To determine the feasibility of development of the power potential of the streams on the reservation, additional data of hydrology and geology of the reservation are needed. More complete stream run-off measurements are required to accurately determine the hydraulic power available from the streams. To establish anticipated costs of construction of both conduits and impounding structures, a more detailed study of geologic conditions is needed. Because of the possibility for a desired integrated development of both power and irrigation from streams flowing on the reservation, it appears advisable to consider their development dependently until such time that development of either is deemed impractical.

Section 12-6: Summary.

12-6.1 Development on Metolius and Deschutes. It appears inevitable that water power development on the main course of the Deschutes and Metolius Rivers will continue. The hydrology and geology of these rivers favor development. Electrical energy consumption is increasing in the northwest. There is no other source of power now available that can economically compete in this region with a program of hydro-electric development. Benefits to the residents of the reservation which result from these developments will tend to be limited to reimbursements for easement concession, and to recreational enterprise. It would not be anticipated that completion of such developments would be a major factor in improvement of stable social-economic conditions on the reservation.

12-6.2 Development within the Reservation. Sufficient data are not now available to accurately determine the feasibility of the hydro-electric development of the streams flowing across the reservation. Additional hydrologic information is needed to determine the expected power available. Geologic information is needed to determine design and estimated costs on required impounding structures, tunnels, and conduits. Regardless of any present attitude shown toward development of these streams, development will probably appear more favorable in the future as the power potential in the adjacent area becomes fully used. It would appear that these streams could be developed to greatest advantage by an agency or utility currently having water power activity in the area.

12-6.3 Coordination of Power and Irrigation. The streams on the reservation appear to have more monetary value for their potential power alone than they do for irrigation alone. However, the benefits to be derived from power would not have as stabilizing an effect on a healthy social and economic climate as would those benefits obtained from a sound irrigation development program. Geology and hydrology features of the reservation would permit a coordinated program for both power and irrigation requiring moderate change in the development as designed for power only. Such a coordinated system would enable more efficient total use of water at a lower investment and operating cost than would be possible for separate systems. Seepage and evaporation losses in the main power canal and conduit system would not be materially increased by irrigation. Conflict of interest in use of water constitutes a major obstacle in the joint development by power and irrigation. Water requirements for full irrigation development of the reservation are so high that it is questionable if the remaining discharge available is attractive to power development.

Section 12-7: Recommendations.

12-7.1 Hydrology Data. To accurately evaluate the water power potential of streams on the reservation additional stream run-off data are needed. Because the power potential as outlined is dependent on headwater flow, the securing of additional discharge information for streams at both upper and lower reaches is recommended. It is suggested that a stream gaging station program be initiated that would meet these requirements. Such a program should be supervised by the Hydrology Division of the U. S. Geological Survey.

12-7.2 Geology Data. Additional geologic data are needed to accurately evaluate the problems to be encountered in canal, conduit, and tunnel construction of the proposed power canal. Information is needed pertaining to the geology of the dam sites at the Schoolie Pasture and the Hot Springs.

12-7.3 Irrigation Development. Because of the many advantages of a coordinated irrigation and power development of streams on the reservation, it is suggested that no extensive irrigation construction be attempted until such time that it is possible to accurately ascertain the power potential.