MIDDLE FORK IRRIGATION DISTRICT

WATER MANAGEMENT / CONSERVATION PLAN

Middle Fork Irrigation District
Post Office Box 291
Parkdale, Oregon

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Assisted by
H & R Engineering, Inc.
Salem, Oregon

Oregon Water Resource Congress
US Bureau of Reclamation

Water Management / Conservation Plan

MIDDLE FORK IRRIGATION DISTRICT

PARKDALE, OREGON

I. Description of District

A. History of Area and District

Middle Fork Irrigating Company

Middle Fork Irrigating Company filed its Articles of Incorporation with the State of Oregon October 5, 1896. Board members were paid $1.50 per day to build the first ditch from the East Fork of the Middle Fork of the Hood River (Eliot Branch). The first appropriation for water was made in 1897 for 250 miner inches [6.25 cubic foot per second (cfs)] of water from the East Branch of the Middle Fork Hood River (Eliot Branch). On November 19, 1906, an additional 3000 miners inches [one miner's inch equals 1/40 of a cubic foot per second (cfs)] or 75 cfs of water was filed on from the Middle Branch of the Middle Fork Hood River (Coe Branch). The purpose was to supplement appropriations from smaller streams and for further development of lands under their system.

The Middle Fork Irrigating Company claimed a total of 3,250 acres to be irrigated through their system in the Hood River Adjudication proceeding. The Middle Fork Irrigating Company was dissolved March 19, 1921.

The Middle Fork Irrigation District

The Middle Fork Irrigation District was organized, in 1921 under the laws of the State of Oregon. The District was organized as a taxing body for the purpose of delivering irrigation water to properties within its territory. It is administered by a Board of Directors elected by registered voters of the District. Currently water is delivered to 611 tax lots managed by 403 water users. Revenues are derived from user fees on land within the District and power generation revenues. Expenditures are made for the operation, maintenance and improvement of the irrigation system.

In the early 1960's Sheldon Laurance, Chairman MFID, signed a project agreement with the USDA Soil Conservation Service for joint construction of Clear Branch Dam, Clear Branch Conduit, the Sediment Basin and over 45 miles of distribution pipelines. Initially over 25 pressure reducing stations were used to limit pipeline pressures. Over the years several more pressure reducing stations have been added to the system and one large pressure reducing station with hydropower generating facilities.

Glacier Irrigating Company

The Glacier Irrigating Company was allowed a total of 3,165 acres to be irrigated from Sand Creek (Polallie Creek), with a priority date of March 15, 1906. The Glacier Irrigating Company last used Sand Creek as a source of water in the summer of 1949[1]. The Glacier Irrigating Company also had water rights from Cold Springs Creek. Sand Creek (Polallie Creek) is a tributary of the East Fork Hood River.

Glacier Irrigating Company was absorbed by MFID on or about June 30, 1956. No statement and proof of claim was filed by MFID claiming the use of the water from Sand Creek and in 1973 an order was entered canceling the vested right of 569 acres. Middle Fork Irrigation District currently provides irrigation water to land formerly within the boundaries of the Glacier Irrigating Company, which are located in the southeast portion the MFID.

Clear Branch Dam

[1] Supplemental Findings of Fact and Order of Determination Hood River and its Tributaries, Hood River County, OR. James E. Sexson, Water Resources Department, January 5, 1977

In 1968 the MFID and the USDA Soil Conservation Service under Public Law 566 constructed Clear Branch Dam. The purpose of the dam was to provide irrigation to 8420 acres in the Upper Hood River Valley. At that time, hydroelectric generation was considered and rejected, primarily due to the cost of extending power lines to the dam. Clear Branch (Creek) and Pinnacle Creek flow into Laurance Lake. At full pool, Laurance Lake has 130 surface acres and 3565 acre feet of storage capacity. The lake helps provide irrigation water to 6,376 acres of pears, apples, cherries and other crops in the Upper Hood River Valley. The Hood River Valley is the largest fruit-growing District in the State of Oregon. MFID and ODFW established minimum stream flows below Clear Branch Dam in 1962. The ODFW/MFID minimum flow agreement below Clear Branch dam was amended in 1982 for construction and operation of the hydro electric project and most recently, in 2007 through the development of the MFID Fisheries Management Plan.

Hydroelectric Power Generation Facilities

In 1985 MFID was issued Federal Energy Regulatory Commission (FERC) Project Number 4458. At capacity these turbines can produce approximately 25,000 megawatt/hours of electricity annually. The completed hydroelectric project came on line in March and was dedicated October 18, 1986. The project was conceived and designed to be compatible with the District's primary function, delivery of irrigation water to District patrons. Waters of Clear Branch, Eliot Branch and Coe Branch of the Middle Fork of the Hood River are used for generation of electricity.

The three powerhouses, allowing for differences in turbine configuration and site requirements, are similar in design and construction. Pelton wheel turbines are used in powerhouses one and three, where water is returned to atmospheric pressure. The Francis turbine in powerhouse two resides within a pressurized pipeline system. Financing for the project totaled 7.5 million dollars.

Middle Fork Irrigation District Mission Statement

The primary function of Middle Fork Irrigation District (MFID) is to provide a reliable and economic supply of suitable irrigation water to District members. Incidental water uses include air temperature modification (primarily frost control), orchard and cropland spraying, livestock water and fire protection. As a secondary function, MFID produces hydroelectric power from three small scale hydropower plants. All functions are accomplished within the broad goal of watershed health. Watershed health includes improved fisheries (fish passage, screened intake structures, improved habitat and acceptable temperature levels), reduced sedimentation in clear water tributaries, riparian health, and acceptable turbidity levels.

B. Location, Maps, Climate, Soils

1. Location

The Middle Fork Irrigation District (MFID) is located approximately thirteen miles south and three miles west of Hood River, Oregon. (The city of Hood River is located immediately south of the Columbia River approximately 65 miles east of Portland.) Middle Fork Irrigation District boundaries are the Middle Fork of the Hood River on the west and the East Fork of the Hood River on the east and north. On the south the watershed for the District extends onto the northern slopes of Mt. Hood and includes Eliot, Langille and Coe Glaciers. The small town of Parkdale, is located near the center of MFID irrigated lands. Locally the area is described as being in the Upper Hood River Valley.

MFID occupies a gently sloping to undulating area about 6 miles long (south to north) and about 1½ miles wide (west to east). Irrigated land slopes predominantly to the north. Average slope is a little over 3%. Gently sloping to deeply incised drainage ways bisect the area. MFID irrigated elevations vary from 1300 feet msl at the northern boundary to 2420 feet msl at the southern.

District lands are primarily pear, apple, and cherry orchards. There are a few fields of corn for silage, nursery, berries, hay and pasture. Water application is either by sprinkler or micro (drip, trickle, minispray, etc.) irrigation systems.

Table 1

LOCATION OF IRRIGATED LAND IN THE MIDDLE FORK IRRIGATION DISTRICT

Township	Range 9 East	Range 10 East
1 North	24	18, 19, 20, 21, 28, 29, 31, 32, & 33
1 South	1, 12, &13	5, 6, 7, 8, 9, 17, 18, 19, & 20

Five sub-watersheds (Evans, Trout, Emil, Griswell and Wisehart Creeks) of the East Fork Hood River and five subwatersheds (Clear Branch, Coe Branch, Eliot Branch, Pinnacle Creek, and Rogers Creek) of the Middle Fork Hood River supply water for the MFID.

2. Maps

The following Middle Fork Irrigation District Maps are included at the end of the plan as Appendix C.

8½" x 11" System Map (3 sheets)
11" x 17" General Soils Map (1 sheet)
11" x 17" Topographic Map (2 sheets)

3. Climate

Marine air moving up through the Columbia Gorge and spreading inland into the Hood River Valley and greater Columbia Basin has a significant moderating effect on the more extreme temperatures of both summer and winter. Occasional low winter temperatures are the result of strong projections of very cold continental air from the northeast. Excessively warm temperatures are similarly the result of occasional high pressure during the summer stagnating either over the inland Columbia Basin or western (multistate) Great Basin. Most years' the mean temperatures are not warmer than 96^{o} or lower than 0^{o} F. The frost-free period is 100 to 120 days at 32^{o} F.

Average annual precipitation in the Upper Hood River Valley varies from about 35 inches along the eastside to over 45 inches on the west. Official average annual precipitation recorded at the Parkdale Station is 41.3 inches. Between 70 and 80 percent of precipitation occurs in November through March. Only 5 to 10 percent occurs in June through August. The rest is fairly evenly divided between the April - May and September – October periods.

While most of the precipitation is in the form of rain, there is substantial snowfall almost every winter. Measurable precipitation can be expected on about 145 days a year.

Ambient air relative humidity often reaches 90 to 100 percent during early morning hours in the summer and most any time of the day late in fall and winter. In contrast, during the warmest part of a summer day, it is not unusual to have a mid day relative humidity of 10 to 12 percent, and occasionally even lower. The average is about 35 percent.

Table 2

AVERAGE MONTHLY TEMPERATURE, PRECIPITATION AND EVAPORATION

In The Upper Hood River Valley

Parkdale Station

Month	Mean Daily Maximum Temperature	Mean Daily Minimum Temperature	Average Monthly Precipitation	Average Monthly Evaporation [1/]
	^{o}F	^{o}F	Inches	Inches

January	38	23	7.0	0.6
February	43	26	5.7	0.9
March	50	30	4.9	1.6
April	60	34	2.3	2.6
May	68	39	1.5	3.9
June	73	44	1.0	4.9
July	81	47	0.1	6.3
August	80	45	0.3	5.7
September	74	42	0.8	3.6
October	61	36	3.0	1.8
November	47	30	7.1	0.8
December	41	27	7.8	0.6
Annual	60	35	41.3	33.3

1/ Class A pan evaporation values are measured at the OSU Hood River Valley Agricultural Center located in the Lower Hood River Valley about one mile south of Hood River Oregon. Mean elevation at the Center is about 520 feet mean sea level (msl). MFID elevations vary from 1300 to 2420 feet.

4. Soils

Soils in the MFID are predominantly of the Parkdale - Dee Association.

The Parkdale - Dee Association consists of deep, well-drained and somewhat poorly drained loams and silt loams. Slopes are dominantly less than 8% but range from 0-40%. The warm deep soils were formed in slightly weathered volcanic ash. Predominant soils are Parkdale Loam, 0-8% slope with an Agricultural Capability Class (ACC) of IIe-1 and the Dee Silt Loam, 0-12% slope, ACC IIw-1. Elevations vary from 1000 to over 2500 feet. Average annual precipitation is 35 to 50 inches, the average annual air temperature is 45 to 49 degrees F and the frost-free period is 100 to 120 days. Average MFID irrigated land slope is 3%, with slopes varying from 2% to over 10%.

Parkdale Soil Series: Parkdale soils are well drained. They have a dark brown loam surface layer, brown silt loam subsoil and a yellowish brown loam substratum. Effective rooting depth is more than 60 inches. Soil permeability is moderate. Available water capacity in the profile is 15 to 17 inches. The soil is slightly acid in the surface layer and neutral below.

Dee Soil Series: Dee soils are very similar to the Parkdale soils. Dee soils are somewhat poorly drained. They have a very dark grayish brown silt loam surface layer, brown loam subsoil, and a dark yellowish brown sandy loam substratum. Effective rooting depth is 40 to more than 60 inches. A water table can occur at depths of 2 - 4 feet. Soil permeability is moderate. Available water capacity in the profile is 15 to 17 inches. The soil is slightly acid.

C. Water Rights

MFID has a history of irrigation water rights going back to 1884. A water right from "Trout Creek through the Thomas Ditch for irrigation of 40 acres with a date of priority of 1884"[2] inherited from the Middle Fork Irrigating Company is the oldest water right. Successive water rights were claimed in the 1890s on Trout Creek, Evans Creek, and East Fork of the Middle Fork (Eliot Branch). In the early 1900's rights were acquired on Rogers Creek, Wisehart Creek, and Griswell Creek. A water right for 75 cfs from the Middle Fork of the Middle Fork of

[2] Supplemental Findings of Fact and Order of Determination Hood River and its Tributaries, Hood River County, OR. James E. Sexson, Water Resources Department, January 5, 1977.

Hood River (Coe Branch) was filed on November 19, 1906. However, the Middle Fork of the Middle Fork (Coe Branch) was abandoned as a source of appropriation in 1969 when Clear Branch Reservoir was completed and pressure pipelines installed, due to the amount of abrasive glacier till suspended in the water. In the 1960s, rights were acquired on Clear Creek, Emil Creek and the Clear Branch Reservoir (Laurance Lake). Additional water rights were acquired on Coe Branch in 1985 and 1987. Past Irrigation District and on-farm conservation efforts have made MFID one of the most efficient irrigation Districts in the United States.

Water is delivered in pressure pipelines with sufficient pressure at each turnout to operate sprinkler and micro irrigation systems.

Table 3

MIDDLE FORK IRRIGATION DISTRICT WATER RIGHTS[3,4]

USE	ACRES	C.F.S.	SOURCE	PRIORITY	PRMT/CRT
Irrigation	17.9	0.22	Trout Creek	1892	C 74253
Irrigation	85.0	1.06	Evans Creek	1894	C 74254
Irrigation	75.9	.95	Evans Creek	1896	C 74255
Irrigation	3.1	.04	Evans Creek	1896	C74256
Irrigation	837.6	6.25	E. Fork Middle Fork Hood River	1897	C 74258
Irrigation	12.5	0.16	Trout Creek	1897	C 74257
Irrigation	15.0	0.19	Trout Creek	1898	C 74259
Irrigation	30.0	0.38	Evans Creek	1900	C 74260
Irrigation (Routson)	28.4	0.36	Evans Creek	1901	C 46966

[3] Larry Toll, Watermaster, 11/03/1997

[4] Maximum rate and amount are 1/40th cfs and 3.0 acre feet per acre

Irrigation	123.0	1.54	Rogers Creek	01/19/1910	C 74261
Irrigation	80.0	1.0	Wishart Creek	8/09/1915	C 74262
Irrigation	69.8	.87	Griswell Creek	6/16/1924	C 80478
Irrigation	429.3	4.163	Eliot Creek	6/09/1955	C 74264
Irrigation & Supplemental Irrig.	5232.0 880.0	75.0	Clear Creek & Clear Branch Res.	1/02/1962	S 27788
Supplemental Irrig.	44.0	0.55	Emil Creek trib. To E. Fk. Hood River	4/02/1965	C 46267
Fish Culture & Supplemental Irrigation		3550ac/ft	Clear Branch stored in Clear Branch Resvoir	04/06/1967	R-4862
Fish Culture & Supplemental Irrigation	6012.0	3550ac/ft	Clear Branch Res	04/06/1967	S 31956
Irrigation	8.2	0.10	Eliot & Clear Creek	1/22/1969	C 46268
Supplemental Irrig.	6012.0	25.0	Eliot Creek	3/09/1970	S 51366
Irrigation	4.4	0.06	Eliot & Clear Creek	4/09/1971	C 74265

Table 3

MIDDLE FORK IRRIGATION DISTRICT WATER RIGHTS (continued)[5].[6]

USE	ACRES	C.F.S.	SOURCE	PRIORITY	PRMT/CRT
Irrigation	311.5	3.89	Trout Creek	3/30/1972	S 43519
Supplemental Irrig.	27.5	0.34	Eliot, Clear Creek		
Spray, Fire &Stock	339.0	1.35	Trout, Eliot, Clear Creek		

5 Larry Toll, Watermaster, 11/03/1997

6 Maximum rate and amount are 1/40th cfs and 3.0 acre feet per acre.

Irrigation	6.0	0.08	Evans, Eliot, Clear	9/19/1977	S 42645
Irrigation Frost Protection Fire Protection	500.0 38.3	6.25 5.75 1.0 Max 6.25	Eliot Creek with deficiency made up by Clear Creek	5/1/1980	S 51367
Hydropower		20 10 10 20 15 15	Clear Branch/Res Eliot Branch Creek Coe Branch Creek Clear Branch/Res Eliot Branch Creek Coe Branch Creek	1/26/1981 1/26/1981 1/26/1981 7/14/1982 7/14/1982 7/14/1982	C 84694
Temperature Control Stock Water	73.3	4.375 5.468 9.843	Clear, Eliot Creeks Evans Creek with deficiency made up by Clear Creek	2/20/1981	S 51368
Supplemental Irrig Fire Protection Stock Water Non-Irrig. Season Temp Control	6012.0	29.5 0.25 0.25 10.0 Max 30.0	Coe Creek	8/19/1985	S 51369
Frost Protection	365.21	20.84 15.0	Clear Creek Coe Creek	6/1/1987	S 51370
Irrigation	160.0	480 ac/ft	Laurance Lake Reservoir	01/02/1996	S 53019
Storage for Supplemental Irrigation		10.7 ac/ft	Emil Creek	03/29/1965	C 46266

Spray,Stock,Fire	412.4	1.0	Rogers, Eliot & Clear Ck		

There are no transfers or governmental exchange agreements of note. Rotation scenarios due to supply deficiencies are outlined in section VII.

Sufficient pressure is available at each on-farm turnout to operate sprinkler and micro irrigation systems. Except for Eliot Ditch (sometimes called Eliot Branch to Sediment Basin Canal) and the Glacier Ditch, MFID is a totally enclosed pressure pipeline distribution system. Piping of the Glacier Ditch is scheduled to be completed in the spring of 2012. Pipeline pressures are provided by gravity. Prior to PL-566 Project construction in the 1960's most District water was delivered via open canals and ditches. On-farm users used pumps to pressurize water for sprinkler irrigation systems.

Minimum Stream Flows

During the permitting process for the construction of Clear Branch Dam, a stipulation to application numbers R-37284 and S-37285 was signed on March 21, 1962 by Middle Fork Irrigation District, the Oregon State Game Commission and the Fish Commission of Oregon. That stipulation sets a minimum reservoir pool of 150 acre feet (surface area ~ 11.5 acres) and minimum stream flows in Clear Branch below the dam. In 1982, that stipulation was modified by MFID and the Oregon Department of Fish and Wildlife during the permitting process for hydroelectric facilities to state actual stream flow up to 30 cfs will be passed from September 16, throughout the remainder of the non-irrigation season. On May 15th stream flow can be reduced to 3 cfs. The minimum flow agreement was further modified through the development of the MFID Fisheries Management Plan in 2007. The 2007 modification provides for a voluntary 5 cfs minimum flow rate below Coe and Eliot diversions and modifies the rate and timing of flow releases below Clear Branch dam. On other streams within the District, self imposed minimum stream flows have been in affect for at least 20 years. No streams are intentionally allowed to dry up. Target flow rate downstream of each diversion is at least one cubic foot per second (cfs). MFID staff use one half cfs as an absolute minimum flow. (One cfs = 450 gallons per minute.)

D. Storage Facilities / Water Supply Description

Five sub-watersheds (Evans, Trout, Emil, Griswell and Wisehart Creeks) of the East Fork Hood River and five sub-watersheds (Clear Branch, Coe Branch, Eliot Branch, Pinnacle Creek, and Rogers Creek) of the Middle Fork Hood River supply water to the MFID. Fall through spring runoff water from Clear Creek and Pinnacle Creeks is stored in Laurance Lake behind Clear Branch Dam. MFID operates an "on-demand" supply and distribution system. Water users opening and closing field turnout valves determine District flow rates and volume, especially during the irrigation season. District staff continuously monitor flow rates, and where needed, adjust flow rate and pressure.

E. Points of Diversion

There are eleven points of diversion for the Middle Fork Irrigation District. Heavy steel mesh screens prevent fish and debris from entering canals and pipelines.

Table 4

MIDDLE FORK IRRIGATION DISTRICT POINTS OF DIVERSION

Diversion Name	Location
Clear Branch Dam (including Clear Creek and Pinnacle Creeks)	NE ¼ NW ¼ Section 27 T 1 S, R 9 E
Coe Branch (Creek)	SE ¼ NE ¼ Section 27 T1 S, R 9 E
Eliot Branch (Creek) (E.Fk.Mid.Fk)	SW ¼ NE ¼ Section 26 T 1 S, R 9 E

Upper Evans Creek	NW ¼ NE ¼ Section 25 T 1 S, R 9 E
Trout Creek (Sato Diversion)	NE ¼ SE ¼ Section 1 T 1 S, R 9 E
Evans Creek (Higgins Diversion)	NE ¼ NE ¼ Section 7, T 1 S, R 10 E
Emil Creek (Emil Pond)	SE ¼ SE ¼ Section 32 T 1 N, R 10 E
Trout Creek (Dykstra Diversion)	SW ¼ NW ¼ Section 32 T 1 N, R 10 E
Wisehart Creek (Alexander Diversion)	NE ¼ NE ¼ Section 32 T 1 N, R 10 E
Griswell Creek (Halliday Pond Div.)	SE ¼ NE ¼ Section 8 T 1 S, R 9 E
Rogers Creek Diversion	NE ¼ NW ¼ Section 1 T 1 S, R 9 E

F. Major Features, Operation and Maintenance

1. Major Features

a. Dams

Clear Branch Dam (Laurance Lake)

On January 2, 1962 MFID filed Application numbers R-37284 and S-37285 with the State Engineer of Oregon (OWRD) for a permit to construct a dam and store 3565 acre feet of the waters of Clear Branch, a tributary of the Middle Fork of the Hood River. When full (spillway elevation 2978 feet msl) the surface area of Laurance Lake is approximately 130 acres.

Clear Branch Dam is located in the Mt. Hood National Forest in the NE ¼ NW ¼ Section 27 Township 1 South, Range 9 East of the Willamette Meridian. The dam is an earth and rock zone fill approximately 1350 feet long with a top width of 28 feet. Height of the dam is 106 feet and water depth at the spillway crest elevation is 100 feet.[7] Construction was under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566).

Table 6

[7] Watershed Work Plan, Middle Fork of Hood River Watershed, Hood River County, Hood River Soil Conservation District, MFID, USDA-SCS, USDA-USFS, April 1962

LAURANCE LAKE OPERATIONS[8]

Minimum Storage in acre feet	Frequency % of years	Remarks
150	<20	Minimum pool
300	>75	
900	>50	

Minimum flow regimes below Clear Branch Dam are:[9]

a) 3 cfs for the period starting July 10 and extending through October 7 of each year.

b) 50% of calculated reservoir inflow up to 20 cfs from October 8 through July 10.

c) These flows can be reduced at the discretion of the fishery management agencies if it would be in the interest of fishery resources to do so insofar as such reduction does not interfere with the primary function of the reservoir.

Sediment Basin and Dam

The sediment basin and dam is located at the end of the Eliot Ditch in a saddle separating Eliot Branch and Evans Creek watersheds. The headwaters of West Evans Creek begin a short distance down slope to the east. The location is approximately 4.1 miles southwest of Parkdale, OR in SW ¼ SW ¼ Section 24, T1S, R9E WM. The dam is an earth fill structure, 12' tall and 450' long with a reinforced concrete riser for a spillway. Earthfill volume is approximately 5000 cubic yards. The water surface elevation when full is 2830 feet mean sea level (msl). Surface area is approximately five acres with a total capacity of 25 acre feet. The purpose of the sediment basin is to trap glacial sediments. Annual sediment volume trapped is estimated to be two acre feet. Currently District staff limits sediment basin inflow during high sediment yield periods of the year, thus reducing the cleaning requirements.

[8] Per 2007 MFID Fisheries Management Plan Flow Modifications.

b. Diversions

Coe Diversion – The Coe Branch Diversion is located approximately 0.8 miles upstream of the confluence with Middle Fork of Hood River, being within the SE ¼ NE ¼ Section 27 T 1 S. R 9 E. Original construction was completed in December 1987. The Coe diversion was upgraded in the fall of 2009. The dam and drop inlet grate structure was removed and replaced with a 25 ft long angled concrete water entry wall, fish bypass channel and drop pools. An agency approved 50 foot FCA horizontal flat plate dual stage screen was installed. This resulted in the addition of 3 miles of upstream habitat for fish and met water quality standard objectives and restoration priorities in the Hood River Basin. The primary purpose of the Coe diversion is to provide water for power generation and irrigation.

Eliot Diversion - Construction on the Eliot Branch Diversion was started September 13, 1965 and was completed December 10, 1965. Construction Plans where prepared for the Middle Fork Irrigation District and the Hood River Soil and Water Conservation District by the U.S. Department of Agriculture Soil Conservation Service (currently Natural Resources Conservation Service). Due to glacial outbursts/debris torrent events the facilities have been replaced/repaired four times. The Eliot Diversion is located on Eliot Branch (Creek) approximately 1 mile upstream from the Middle Fork Hood River, five miles southwest of Parkdale, OR in SW 1/4 NE 1/4 Section 26, Township 1 South, Range 9 East of the Willamette Meridian. In November 2006, a debris flow completely destroyed the Eliot diversion. The Diversion facilities were rebuilt with a side channel inlet and criteria fish screen in the spring of 2007. From the diversion facilities water enters the Eliot ditch. The ditch provides conveyance of water from the point of diversion to the sediment basin. At the Sediment Basin waters from Clear Branch Dam, Coe Creek diversion and Eliot Diversion can be mixed and distributed into the Volmer pipeline, West Evans pipeline and the Glacier ditch / pipeline.

Upper Evans Creek Diversion – The Upper Evans Creek Diversion is located on Evans Creek approximately 2.4 miles upstream of the confluence with West Evans Creek (5.2 miles from

East Fork Hood River) being within the NW ¼ NE ¼ Section 25 T 1 S. R 9 E. Construction was completed in November 1970. The Upper Evans Creek Diversion supplies water to the Glacier Ditch for irrigation purposes. It consists of a flat panel, creek bed level fish screened diversion and measurement weir.

Emil Pond and Diversion

The Emil pond and diversion is located approximately 1/10 mile west of the town of Parkdale. This diversion consists of a 566 ft long; 23 ft high earth filled dam and a reinforced concrete irrigation outlet structure. The dam crest elevation is 1693 ft. The emergency spillway elevation is 1689 ft. At capacity the surface area of the reservoir is 2 acres with a storage capacity of 10.7 ac/ft.

Rogers Creek , Dykstra, Sato, Alexander, Halliday

Diversions in this group are small, approximately four feet high, flashboard type structures located in the lower elevations of the district north of Parkdale. They are used for diversion by the district as needed and at a minimum annually. With exception of the Rogers Creek structure, during the non irrigation season the flash boards are generally pulled to facilitate fish passage.

c. Pipelines

MFID staff and irrigation water users have been installing pipeline in the distribution system beginning after WWII with the availability of steel invasion tubing. In the late 50's and early 60's the low quality steel tubing began to fail, but water users were hooked on benefits of pipeline deliveries. On-farm benefits included: reduced ditch maintenance, positive pump suction heads, and where pressure was sufficient, operating sprinkler irrigation systems without a pump. There were numerous "pooling agreements" among neighbors who were served from the same source. By the mid 60's many miles of Transite, plastic, and a few heavy gauge, coated steel pipelines were being installed by water users annually.

These pipelines were incorporated into the Middle Fork Irrigation District system as community pressurization developed. After completion of the Clear Branch Dam in the late '60's, large diameter pipelines were installed on the upper (south) end of MFID irrigation laterals, basically completing system pressurization. The delivery system has been totally pressurized for decades. In addition to water conservation the closed pipeline system provides energy conservation since there are no on-farm or District pumps in the system. Three hydroelectric power generation stations and dozens of in-line pressure reducing stations are used to reduce lateral line pressures for on-farm deliveries.

Over 60 miles of buried pipeline varying from 4” to 48” diameter is used to deliver pressurized irrigation water to 6,376 acres of high value farm land.

d. Canals

Eliot Ditch (Eliot Branch to Sediment Basin Canal)

This Canal bears northeast on a ~4% grade from the Eliot Branch Diversion (SW ¼ NE ¼ Section 26 T 1 S, R 9 E) to the sediment basin, a distance of about 0.80 miles. Top width varies from 7 to 9 feet with an average bottom width of about 8'. The canal is trapezoidal with a maximum depth of 3 feet. Flow rates vary from 2 to 25 cfs. Average flow rate when irrigating is about 15 cfs. An evaluation of feasibility for piping the Eliot Ditch revealed it to be economically unfeasible with respect to a prohibitive cost/benefit profile. The high concentration of fine sediment in Eliot Ck provides a sealing layer along the ditch bottom thereby reducing leakage, the sediment load also creates a blockage issue for a would be pipe conveyance requiring an oversized pipe. The relatively short length of ditch does not pose a significant loss of water while the permitting, material and construction costs would be considerable.

Glacier Ditch

This canal consists of two sections: from the Sediment Basin (SW ¼ SW ¼ Section 24 T 1 S, R 9 E) to the Upper Evans Creek Diversion (1.1 miles). The second section leaves the Upper Evans Creek Diversion (NW ¼ NE ¼ Section 25 T 1 S. R 9 E) and extends to the Sutton pipeline (1.2 miles) for a total distance of 2.3 miles. Flow rates vary between 1 cfs and 6 cfs. Around 5 cfs is a reasonable average irrigation flow. From the Sediment Basin this variable width trapezoidal canal bears southeast on ~2% grade to the Upper Evans Creek Diversion. Average width is 8' at the bottom and maximum depth is 3 feet. From the Upper Evans

Creek Diversion the ~2% gradient ditch continues in an easterly direction. A typical cross section would be about 8 feet across the bottom and a depth of about 4 feet. The Glacier ditch is scheduled to be piped by the spring of 2012.

e. Penstocks

Large diameter pipelines installed for power production extend from the sediment basin to three powerhouses. Total length is almost six miles. Pressure in the two-mile long multipurpose Clear Branch (Laurance Lake) to Sediment Basin pipeline is captured at the Sediment Basin by penstock #1. The three steel penstocks have an epoxy lining and a two-layer Polyken tape outer wrap for corrosion protection.

Table 7

MIDDLE FORK IRRIGATION DISTRICT PENSTOCKS

PENSTOCK	ENTRANCE LOCATION
Penstock #1	SW ¼ SW ¼ Section 24 T 1 S, R 9 E
Penstock #2	SW ¼ SE ¼ Section 18 T 1 S, R 10 E
Penstock #3	SW ¼ SW ¼ Section 6 T 1 S, R 10 E

Clear Branch to Sediment Basin Pipeline is a concrete cylinder pipe (CCP) about two miles long. The pipeline carries water for both irrigation and power. The pipeline begins with about 1000 feet of 42" diameter pipeline then decreases to 36" diameter for the remainder of the length. A branch 30" diameter coated and lined steel pipeline approximately 1700 feet in length ties in the Coe Branch Diversion as a water source. Nearly 1400' of this pipeline was replaced with 42” HDPE after the Nov 2006 debris flow which destroyed sections from Eliot creek past the settling pond.

Penstock #1 begins at the Sediment Basin joining with the 36" pipeline from Clear Branch Dam and directly connects Laurance Lake to the power turbine at Powerhouse #1. The 36" steel pipe is 8900' long. Water is discharged into the atmosphere after passing through the Pelton water turbine

Penstock #2 consisting of 8360' of 26" and 2000' of 48" diameter pipe, begins immediately downstream of Powerhouse # 1. Paralleling the Upper Lava Bed irrigation pipeline for a portion of it’s length, penstock #2 delivers water to the turbine in Powerhouse #2. Remaining pressure downstream of the Francis water turbine at Powerhouse #2 is captured by Penstock #3

Penstock #3 begins at Powerhouse #2 paralleling the route of the Lower Lava Bed irrigation pipeline west to the former site of a 16" pressure-reducing valve (station) that was replaced by Powerhouse #2. The pipeline then extends north to the pressure reducing station on Red Hill Road. This penstock is constructed of 4345 feet of 28" and 5670' of 26" diameter pipe. From the Red Hill Road pressure reducing station, a 30" diameter pipe 1220' long carries the water west along Red Hill Road to Powerhouse #3. At powerhouse #3 water discharging into the atmosphere is directed into Rogers Creek or used for down slope irrigation.

f. Powerhouses

Hydroelectric power is generated at three locations year around utilizing the Middle Fork Irrigation District water distribution system. In addition to operating generators dozens of in-line pressure reducing valves are used to control excess pipeline pressures. During the irrigation season generator discharge waters can be used for down slope irrigation. Power Houses, along with the installation of several thousand feet of large diameter pipeline were completed in 1985 and 86. Several in-line pressure-reducing valves were also eliminated.

Powerhouse locations are:

Table 8

MIDDLE FORK IRRIGATION DISTRICT POWERHOUSES

POWERHOUSE	LOCATION
Powerhouse #1	NE ¼ SW ¼ Section 18 T 1 S, R 10 E
Powerhouse #2	SW ¼ SW ¼ Section 6 T 1 S, R 10 E
Powerhouse #3	NE ¼ SW ¼ Section 31 T 1 N, R 9 E

Within each powerhouse are water turbine generators, control panels and the required hydraulic control and station service equipment. The three powerhouses, allowing for differences in turbine configuration and site requirements, are similar in design and construction. Pelton water turbines are used in powerhouses one and three, where water is returned to the stream at atmospheric pressure. The Francis turbine in powerhouse two is a totally enclosed pipeline system, where the operating head is determined by downstream conditions. Financing for the hydroelectric project totaled 7.5 million dollars.
The three powerhouse buildings are similar in design and construction. Each is a pre-engineered, rigid frame, steel building with thermal insulation and having sound deadening systems to reduce the exterior noise level to acceptable limits. Exterior color of powerhouses blends with the surrounding landscape. Landscaping and screening have been installed.

Table 9

GENERATOR CONFIGURATION

Item	Powerhouse #1	Powerhouse #2	Powerhouse #3
Turbine type	Impulse (Pelton)[1/]	Reaction (Francis)[1/]	Impulse (Pelton)[1/]
Available Head @ 40 CFS	760'	320'	268'[2/]

Rated Capacity	2050 kW	500 kW	800 kW
Generation Voltage	4160 v	480 v	480 v
Guaranteed Efficiency	85.2%	85.2%	83.14%
Est. Annual Output	14.9 GWh[3/]	3.2 GWh[3/]	4.7 GWh[3/]

1/ Pelton type turbines discharge to the atmosphere. A Francis turbine is constructed in-line where total head available is controlled by downstream conditions.

2/ Plus available head from powerhouse #2.

3/ Giga watt-hour

Electrical Equipment

Exterior to each powerhouse are: (1) a switchyard containing the step up transformer which converts generator voltage to a line voltage of 12,460 volts; (2) the station service transformer, which supplies the powerhouse electrical requirements even when there is no generation; (3) the main circuit breaker and its related metering and controls and (4) the remote metering System/Transfer Trip panel, which is intertied directly to the Bonneville Power Administration substation at Mount Hood. Power lines and poles are owned and maintained by Hood River Electric Cooperative.

2. Operation and Maintenance

During the irrigation season primary MFID operation and maintenance responsibilities consist of adjusting flow rates and pressures, cleaning and repairing pipeline intake screens, cleaning fish passage facilities and adjusting, removing or replacing diversion flashboards. Every Friday, and as needed during the week, pressure reducing valves are cleaned and adjusted. Required pipeline replacement, especially in non-orchard areas, is scheduled and performed. Brush control around structures and along access roads and pipeline easements is an annual task. Open ditches are maintained with regular brush removal and control of any woody plants that might compromise the bank stability. Where necessary sediment is removed and flushed.

During the non-irrigation season water is supplied to powerhouse penstocks to generate hydroelectric power. Cleaning intake screens and adjusting flow rates require constant attention. Replacement of old welded steel and wood stave pipelines, primarily in orchard areas, is scheduled and performed. When inclement weather (primarily snow) limits outside work, required equipment maintenance is performed in the District shop.

District staff and Board have a standing annual goal to keep O & M costs as low as possible, while maintaining a dependable, long term water distribution system.

G. SUMMARY

The Middle Fork Irrigation District (MFID) is located in the Upper Hood River Valley. Undulating topography slopes an average of 3% to the north. Deep volcanic loam soils have a very high 15" to 17" available water capacity in the plant root zone. The Middle Fork Irrigation District provides irrigation water to 6376 acres of primarily fruit orchards and other field crops. Over 60 miles of 2" to 48" diameter mostly buried pipeline delivers pressurized water to 611 tax lots serving 6376 acres. MFID is and on-demand pressurized irrigation water distribution system.

Three hydroelectric power generation stations are operated year around. Other water uses are irrigation, orchard and field crop spray, temperature control, livestock water and fire protection. In addition to power generation, dozens of in-line pressure reducing valves are used to limit on-farm delivery pressures.

II. Inventory of Water Resources

A. Existing Water Diversion

MFID staff operate a fully "on demand" supply and distribution system. Flow rate and volume is determined by demand. Diversion requirements are based on ambient air temperature, humidity, wind speed, precipitation, and crop growth stage. The source for diverted stream flow and Laurance Lake storage is seasonal runoff from the slopes of Mount Hood. Middle

Fork Irrigation District staff work closely with resource agencies staff to improve aquatic habitat within the District.

Table 10

TYPICAL MONTHLY IRRIGATION DIVERSION AMOUNTS [1/]

WATER SUPPLY YEAR

Month	Average (2002) acre feet	High (2003)[2/] acre feet	Low (2008) acre feet
April	545	608	141
May	1,108	640	27
June	3,146	3,263	2,250
July	3,718[3/]	3,791[3/]	3,407
August	3,673	3,663	2,814[3/]
September	1,344	1,917	1,911
Total	13,534	13,882	10,550

1/ From MFID annual Water Use Reports to Oregon Water Resources Department.

2/ A high water supply year does not mean water was "wasted". A detailed analysis of carry-over soil moisture, monthly precipitation, ambient air temperature, humidity, and wind speed vs. potential monthly crop evapotranspiration for that specific year is needed to make a determination.

3/ Maximum monthly diversion.

B. Water Storage Releases

Clear Branch Dam (Laurance Lake) is located in the Middle Fork of Hood River watershed. Flows from Clear and Pinnacle Creeks are impounded, filling the reservoir to capacity most years. Water is released at Clear Branch Dam under pressure via a 42" and 36" diameter concrete cylinder pipeline to the distribution system. Minimum reservoir pool and stream flow below Clear Branch Dam are maintained per Oregon Department of Fish and Wildlife, Oregon Department of Water Resources and Middle Fork Irrigation District agreements. See Section F Major Features - Dams for more detail regarding reservoir and stream flow releases.

C. Return Flows

Water discharged from powerhouse #3 can be used for down slope irrigation or returned directly to Rogers Creek. There are no surface or subsurface return flows in the District. The Middle Fork Irrigation District (MFID) distributes water to users via over 60 miles of 4" to 48" buried pipeline. On-farm irrigation water application systems are solid set and hand move sprinkler systems and low volume mini spray/sprinklers or drip micro systems. Big gun (water cannons) and wheel line sprinkler systems are used on a few farms growing nursery stock, corn for silage, berries, pasture and hay. Field runoff is nonexistent due to good irrigation water management, cost of irrigating, high soil profile water holding capacity and overall deficit irrigation. Irrigation systems apply water at rates less than the soil intake rate. A large percentage of soil surface is protected by permanent grass cover.

D. Acreage of Commonly Grown Crops

The District maintains assessment information for each acre served. All crops grown in the District were included in the determination of District water needs based on crop evapotranspiration (ET) and crop irrigation requirement (IR). Seasonal ET and IR for apples and cherries were close enough to combine. Pear, apple and cherry orchards represent 95 % of the total irrigated crops in MFID. Because of the quasi-permanent nature of orchards, acres of each crop grown vary only slightly from year to year. Types and acreage of irrigated cropland, in the District are as follows:

Table 11

CROPS GROWN IN THE MIDDLE FORK IRRIGATION DISTRICT

Crop	Acres	% of total area
Pear Orchards	5350	84%
Cherry Orchards	420	7
Apple Orchards	250	5
Alfalfa Hay	80	1
Corn for silage	80	1
Pasture	80	1
Nursery	75	1
Berries	30	<1
Asparagus	10	<1
Total irrigated cropland	6375	100%

E. Types of Irrigation Systems

The principal irrigation water application method in the MFID is sprinkler, primarily solid set and hand move lateral systems in orchards. Open irrigated fields i.e. corn for silage, nursery, hay and pasture may use big guns (water cannons) or wheel line laterals.

Approximately twenty five percent of the orchard area receives water using the micro irrigation application method. Typical MFID micro irrigation systems are minispray or mini sprinkler and drip/trickle emitters.

F. Classification of MFID Water Uses

Table 12

MIDDLE FORK IRRIGATION DISTRICT WATER USES

Typical MFID water use	Approx. %
Irrigation of crops[9]	30
Power generation[10]	67
Temperature control	2
Orchard spray, stock water, and fire protection	1

Table 12a

MIDDLE FORK IRRIGATION DISTRICT ACCOUNTS BY USE

Use of MFID supplied water	Number of Accounts
Irrigation of crops[11]	403
Power generation[12]	1
Temperature control	18
Orchard spray, stock water, and fire protection	403

G. Water Quality

MFID facilities divert stream flow for irrigation, power generation, temperature control, orchard and cropland spraying, fire protection and stock water purposes. The source of

[9] During the growing season water may be used for power generation prior to down slope irrigation water delivery.
[10] Water is diverted for power generation year around and is not included in the irrigation water supply.
[11] During the growing season water may be used for power generation prior to down slope irrigation water delivery.
[12] Water is diverted for power generation year around and is not included in the irrigation water supply.

water for Laurance Lake is Clear Branch and Pinnacle Creek. These non-glaciated, heavily forested watersheds produce clear cold water year around.

Streams originating from glaciers, namely Coe Branch and Eliot Branch vary from clear and cold most of the year to heavily laden glacial sand bearing streams in July and August. Glacial sand (glacial flour) consists of colloidal clay like particles to highly abrasive flake shaped rock chips. Release of glacial sand is a natural occurring process. Glaciers recede each summer due to warm summer temperatures, exposing very steep (~1 ½ : 1), loose, highly erodible soils along each side. Daily soil moisture and temperature fluctuations plus gravity augment the erosion process. Very steep stream gradients carry soil materials eroded from the sides down slope.

Internal water sources, i.e. Trout, Rogers, Wisehart, Emil Creek, etc. originate from non-point, high volume springs. Numerous, ephemeral, non-point inflows increase stream flow volume as the streams progress down slope. These natural flowing springs are not affected by irrigation practices. Deficit irrigation using sprinklers on very high water holding capacity soils is no doubt part of the reason. With the exception of water diverted from Coe Branch and Eliot Branch during summer and early fall months, over all water quality is very good. With these streams summer receding glaciers expose very steep, unstable side slopes that yield copious quantities of glacial sand (colloidal clay to sharp rock flakes). During the balance of the year water quality from Coe and Eliot can be very good. Sprinkler and micro irrigation systems are used in the Middle Fork Irrigation District, thus there is no field runoff.

III. District Water Budget

A. Seasonal Water Usage

The Middle Fork Irrigation District distribution system is a closed pipeline facility. Water diverted is also listed in Chapter II. Inventory of Water Resources, Section A - Existing Water Diversion.

Table 13

TYPICAL MFID DIVERSION

Seasonal Total in acre feet

	Average ('02) Water Year	High ('03) Water Year	Low ('08) Water Year
Diversion [1/]	13,889	14,262	10,550

1/ Composite of weirs and in-line flow meters.

B. Surface Return Flow from Irrigated Cropland

There are no surface return flows from irrigated cropland due to good water management, cost of irrigating, deep very high available water capacity soils and deficit irrigation. Sprinkler and micro irrigation systems are used. Irrigated cropland, predominately pear, apple and cherry orchards are largely protected by permanent grass ground cover.

C. Subsurface Flows into Canals or Return Drainage Water

There are no subsurface return flows from irrigated cropland due to good water management, deep very high available water capacity soils, cost of irrigating, and deficit irrigation practices. MFID delivers water in a closed pipeline distribution system. Sprinkler and micro irrigation systems are used on-farm.

D. Canal, Lateral and Reservoir Seepage Losses

Design seepage below Clear Branch Dam (Laurance Lake) in addition to releases of stored water and natural springs is used to satisfy agreed to minimum stream flows.

Eliot Ditch (Eliot Branch to Sediment Basin Canal), and Glacier Ditch are the only open water conveyance facilities operated by the Middle Fork Irrigation District. (Glacier Ditch will be fully piped by Spring 2012.) Except for two small turnouts on the Glacier Ditch, there are no water user turnouts on these open conveyance facilities. Minimal ditch seepage losses, primarily due to rodent activity, occur in forested areas high on mountain slopes. On the valley floor pipeline leaks are insignificant.

Table 14

SUMMARY - ESTIMATED DISTRICT WATER LOSSES

Irrigation Season Total in acre feet

	Average ('02) Water Year	High ('03) Water Year	Low ('08) Water Year
Diversion [1/]	13,889	14,262	10,550
Average year crop irrigation water requirement (IR) [2/]	15,594	15,594	15,594
On-farm losses	<10%	<10%	<10%

1/ Composite reading of in-line flumes, weirs, and meters

2/ OSU published 5 out of 10 (average) crop irrigation water requirement (IR) with full irrigation, in acre feet; calculated for the MFID crop mix grown on 6365 acres in the Lower Hood River Valley. MFID, being higher in elevation, crop water use is expected to be slightly less. Irrigation Requirement = crop evapotranspiration minus effective precipitation for an average year (IR=ET-Pe) or for MFID, IR = 2.45 acre feet per acre. On-farm water use seldom approaches MFID capacity.

E. Spills

Except for the Eliot Ditch (1.0 mile), and the Glacier Ditch (2.3 miles), the Middle Fork Irrigation District distribution system is fully enclosed. (Glacier Ditch scheduled to be piped by spring of 2012). There are no operational or emergency spills from district pipelines. Pipeline leaks are minimal. The three power generating stations are an integral part of the water distribution network.

F. Farm Deliveries

Turnout valves are used to deliver irrigation water to 611 tax lots. Sufficient pressure and volume is available to operate a fully on-demand water delivery system. Sprinkler and micro irrigation systems are used to apply irrigation water to the land. Deep volcanic loam soils in the MFID have a very high available water capacity measured at 3.5"/ft or 15" to 17" in the crop root zone. Irrigation frequencies, depending on how much water is applied, can be 15 to 30 days or longer. To maintain a lower soil water tension, on-farm irrigation decision-makers can choose to apply lighter irrigation's more frequently.

1. Average Crop Water Use

The maximum crop evapotranspiration (ET) and irrigation requirement (IR) occurs in July or August, when the ambient temperature is the highest, crop growth (foliage) and soil surface evaporation is the greatest and precipitation is the least. The predominant irrigated crop in the District is pear orchards.

For the analysis in this report, plant evapotranspiration and irrigation water requirements were determined from Oregon Crop Water Use and Irrigation Requirements, OSU Extension Service Publication 8530, dated March 1999.

Table 15

CALCULATED FULL SEASON CROP EVAPOTRANSPIRATION (ET) AND IRRIGATION WATER REQUIREMENT (IR)

SEASONAL

Crop	Acre	Crop ET [1/] (acre inches)	Effective Precipitation [2/] (acre inches)	Crop IR [3/] (acre inches)
Pear Orchards	5350	38.74	9.79	28.95
Apple Orchards	420	41.92	10.03	31.89
Cherry Orchards	350	41.92	10.03	31.89
Alfalfa Hay	80	29.01	4.88	24.13
Corn for silage	80	25.74	3.33	22.41
Grass Pasture	80	35.00	8.30	26.70
Nursery	75	24.57	3.18	21.39

Berries	30	17.56	3.62	13.94
Asparagus	10	19.88	3.66	16.22
Total Irrigated	6375	39.14” 4/	9.70”	29.43” 4/
			Average IR =	2.45 AF/ac

1/ OSU Published 5 out of 10 years (average) crop evapotranspiration (ET) and irrigation water requirement (IR) in acre inches per acre for crops grown March through November at The Mid Columbia Agricultural Research and Extension Center (MCAREC). The MCAREC is located about one mile south of Hood River, OR in the lower HR Valley. Average elevation at the MCAREC is about 520 feet msl. MFID elevations vary from 1300 feet msl to 2420 feet msl, thus crop ET is probably slightly less than values shown. Values are for a fully irrigated crop, where water is not a growth-limiting factor.

2/ Effective precipitation (Pe) is the amount of precipitation that falls during the crop growing season available to help meet crop evapotranspiration, in acre inches per acre. It does not include precipitation that is lost to runoff, deep percolation or evaporation before crop use.

3/ OSU published 5 out of 10 (average) crop irrigation water requirement (IR) with full irrigation, in acre inches per acre. IR is ET minus Pe.

4/ Weighted crop irrigation water requirement for MFID crop mix grown in the Lower Hood River Valley. Upper Hood River Valley IR is probably slightly less.

Table 16

CALCULATED MFID PEAR ORCHARD IRRIGATION WATER REQUIREMENT FOR 5350 ACRES DURING AN AVERAGE YEAR (2002)

	Full Irrigation			Deficit Irrigation	
	Pear IR Ac in/ac	Pear IR AF	AF Delivered To 6365 Ac. in 2002 [1/]	AF Delivered To Pears in 2002 [2/]	Pear Percent Deficit
April	1.42	633	485	407	36 [3/]
May	3.90	1,739	986	828	52
June	5.71	2,546	2,800	2,352	8
July	7.87	3,509	3,309	2,780	21
August	6.38	2,844	3,269	2,746	3
September	3.43	1,529	1,196	1,005	34
October	0.16	71	315	265	0
	Totals	12,871	12,425	10,383	26% [4/]

1/ The year 2002 was selected to represent an average water delivery year. Acre feet diverted in 2002 was within 10 acre feet of the arithmetic eight year average.

2/ Delivery rationed – 5350 acre pears divided by 6365 total MFID acres = 84%

3/ Winter soil moisture carry over is used to partially meet crop water needs during the early part of each growing season. Were it not for frost control, water would not be applied in March, April and early May most years.

4/ Average of months with a deficit water supply.

2. Deficit Irrigation

Deep volcanic loam soils in the MFID have a very high available water capacity (AWC). This ability to store significant amounts of water (15 to 17 acre inches) in the soil profile maximizes the use of winter precipitation to meet early growing season plant water needs. This high AWC also allows a 15 to 30-day or longer irrigation frequency. It is the on-farm water manager's prerogative to apply less water more often or more water less frequently. With either regime, deep percolation (water moving below the plant root zone) can be non-existent. Implementing deficit irrigation during non-critical crop growth periods can be a very effective water management technique having little, if any, negative consequences. Pear, apple and cherry trees are most sensitive to available soil moisture conditions during fruit set, sizing of fruit before harvest and during bud set for next year's crop.

A number of USDA Agricultural Research Service and State University researchers have analyzed the economics of deficit irrigation in specific circumstances and have concluded that this technique can increase net farm income. Deficits from 15 to 60% were shown to be economical with some crops. Potential benefits of deficit irrigation are derived from two factors: increased irrigation application efficiency and reduced irrigation costs (i.e. labor and scheduling other field operations). For additional information regarding deficit irrigation practices, a published peer reviewed paper titled "PERSPECTIVES ON DEFICIT IRRIGATION" by Dr. Marshall English and Syed Navaid Raja has been included in this Plan as Appendix B.

3. Average On-Farm Irrigation Efficiency

The following table represents typical on-farm irrigation system design efficiencies and overall seasonal irrigation efficiencies of various irrigation methods and systems used in the Middle Fork Irrigation District. Historically USDA Natural Resources Conservation Service has provided on-farm evaluations of single event and seasonal irrigation's for a variety of irrigators in several locations in Oregon, i.e. Medford/Central Point, Ontario, Hood River, Grants Pass, etc. The findings of these evaluations, plus many from other states, support the values presented as "average overall seasonal on-farm irrigation efficiencies".

For a District wide overall seasonal irrigation efficiency to closely match system design efficiency, all irrigators must be diligent in practicing above average irrigation water management including good irrigation scheduling techniques. This is not a reasonable assumption to make. However, in the Middle Fork Irrigation District very high AWC soils and deficit irrigating following fruit set early in the growing season helps increase irrigation efficiencies.

Table 17

AVERAGE ON-FARM IRRIGATION EFFICIENCIES

Irrigation Method	Irrigation System	Potential Irrigation System Design Efficiency	Actual Irrigation System Design Efficiency [1/]
Sprinkler	Solid set and hand move	85 - 95	80 – 95
Sprinkler	Big gun (water cannon)	60 - 70	55 – 65
Micro	Drip and Mini Spray	85 - 90	80 – 90

1/ Good water management, mature orchard crops, cost of irrigating and deficit irrigating help increase on-farm irrigation application efficiencies. Reduced wetted area, excessive wind, shallow soils, and neglecting to turn water off when the irrigation set time is finished all decrease application efficiencies.

Reference: NRCS, National Engineering Handbook, Part 652, "Irrigation Guide" 1997; NRCS "Farm Irrigation Rating Index", A Method for Planning Evaluating and Improving Irrigation Management, 1991; ASCE, Proceedings of 1991 National Irrigation and Drainage Conference, p24.

4. District Wide Overall (On-Farm) Water Use Efficiency

Except for Eliot Ditch (1.0 mile) and Glacier Ditch (2.3 miles) and local streams, the Middle Fork Irrigation District distribution network is a closed pipeline system. The historic use of local streams as a means of conveyance to deliver water to pipeline diversion structures located on the valley floor has been completely eliminated in the Middle Fork Irrigation District. Water is delivered to users "on-demand" at sufficient turnout pressure to operate on-farm sprinkler and micro irrigation systems. The closed pipeline distribution system allows for a near direct transfer of on-farm application efficiencies to District wide values. Almost all water lost can be attributed to open water conveyance, and as stated several times, the Glacier Ditch will be piped by spring of 2012. Estimated Middle Fork Irrigation District water application efficiency is over 90%.

Sprinkler Irrigated Lands

The estimated overall seasonal irrigation efficiency for sprinkler irrigated lands (6376 acres) is 90 %. Or, it can be said, the plant uses over 90% of applied water. This very high efficiency is due to a very high soil AWC, good water management and deficit irrigation being practiced. The 10 % losses, of which most are unavoidable, are estimated to be 4% to on-farm deep percolation, and 6% to inadequate pattern distribution uniformity, wind drift, evaporation from plant and soil surfaces, irrigation system pipeline/valve leaks etc. These estimates are based on the above tables, and from professional field experience.

Micro Irrigated lands

The estimated efficiency for micro irrigated lands (1,600 acres) is 85%, based on above table and from professional experience. Deep percolation is perhaps the greatest loss estimated as 12%. Inadequate pattern distribution uniformity, wind drift, evaporation from plant and soil surface surfaces, pipeline leaks etc. contribute to the remaining 3% loss.

District wide weighted average

The on-farm seasonal weighted average (for both sprinkler and micro irrigated lands) is estimated to be 90%. Because MFID is a closed pipeline system, this average District wide on-farm efficiency becomes the District efficiency. Average calculated District delivery needs (and efficiencies) are as follows:

Table 18

MFID WATER BUDGET – AVERAGE CONDITION (2002)

Item	Average Year Delivery	Average Year Irrigation Requirement (IR)	Estimated On-Farm Conveyance Efficiency	Typical On-Farm Irrigation Efficiency
Average Year Deliveries for 6,376 acres [1/]	12,360 AF (1.95 AF/acre)			
Delivery needs for 6,376 acres [2/]				
Sprinkler irrigated lands (6047 acres)	16,508 AF	2.73 AF/acre [5/]	100%	90%
Micro irrigated lands (328 acres)	916 AF	2.88 AF/acre [5/]	100%	85%
Gross Delivery needs (meeting full season crop IR)	17,424 AF			
Average Year Deficit	5,064 AF			
LOSS ESTIMATES (calculated using delivery needs)				
Unrecovered On-farm Sprinkler and Micro Conveyance Losses	0 AF			
Runoff (RO) from sprinkler and micro irrigated lands with a typical irrigation efficiency of 90%	0 AF			
Deep Percolation (DP) from sprinkler irrigated lands [3/]	660 AF			
Deep Percolation (DP) from micro irrigated lands [3/]	110 AF			
Evaporation, wind drift, etc. losses from sprinkler irrigated land [4/]	990 AF			
Evaporation, wind drift, etc. losses from micro irrigated land [4/]	27 AF			

Total Losses	1,787 AF

1/ Actual water delivered April through October 2002 is used to represent the average year, actual water used was within 10 AF of the eight year (1996 – 2003) arithmetic average having complete records available.

2/ Calculated delivery needs are based on OSU published IR for crops grown at the Mid Columbia Agricultural Research and Extension Center (MCAREC) in the Lower Hood River Valley. The weighted crop irrigation requirement for Middle Fork Irrigation District crop mix at that site is 2.45 AF/acre. Average elevation for the MCAREC is about 520 feet msl. Elevations in the Middle Fork Irrigation District vary from 1300 feet to 2420 feet msl, thus actual plant water needs (delivery needs) are probably slightly less than shown.

3/ Deep percolation (soil water moving below the plant root zone) is estimated to be 4% for sprinkler and 12% for micro irrigation systems.

4/ Evaporation, wind drift, etc. losses are estimated to be 6% for sprinkler and 3% for micro irrigated land.

5/ Average crop IR (2.45 AF/Ac.) divided by Irrigation Efficiency.

4. Deep Percolation

Deep percolation losses are estimated to be well within design potential with both sprinkler and micro irrigation systems. In the Middle Fork Irrigation District deep percolation (soil water moving below the plant root zone) from sprinklers is virtually eliminated due to good water management, a very high available water capacity (AWC) soil and deficit irrigation. District wide deep percolation losses are estimated to be 4% with sprinklers and 12% percent with micro irrigation systems. Almost all deep percolation losses using micro irrigation systems is the result of less than perfect irrigation frequency decisions, namely applying water when tree and field crops could wait a few more days. Even with the best irrigation water management, some water loss is unavoidable.

Table 19

AVERAGE YEAR DISTRICT WIDE, ON-FARM IRRIGATION WATER SUPPLY, USE AND APPLICATION SYSTEM LOSSES

(for 6365 irrigated acres)

Water Distribution	Water Application /Losses
Average year farm deliveries (2002)	12,360 AF
Estimated 8" winter precip. soil moisture carry over 1/	4,243 AF
Average Year Crop Water use, IR 2/	-15,594 AF
Total on-farm losses 3/	-1,787 AF
Average deficit delivery	-778 AF

1/ It is estimated 8" of winter precipitation is stored in the soil within the plant root zone most years. This amount applied to 6365 acres reduces the gross irrigation requirement 4,243 acre feet.

2/ Calculated consumptive use IR is based on crop mix and acres grown on MFID irrigated lands. The year 2002 was selected to represent an average year. Average year irrigation water requirement (IR) times acres irrigated = acre feet; or 2.45 acre feet per acre (6365 acres) = 15,594 acre feet. Actual crop water needs can be greater or less than calculated average values.

3/ Total on-farm losses include deep percolation, wind drift, evaporation, inadequate pattern uniformity, etc. Some losses are unavoidable.

Drainage Requirements

Most soils in the MFID are naturally well drained. In general, improved surface drainage and salinity management etc. are not required. However, scattered areas with in the District do require water table control (subsurface drainage).

G. Summary — District Wide Water Budget

Table 20

DISTRICT WATER BUDGET SUMMARY

Item	Average WY2002	Average for highest three years	Highest year 2000	Lowest year 2008
Diversion [1/]	13,879 AF (2.18 AF/acre)	14,548 AF (2.29 AF/acre)	15,167 AF (2.38 AF/acre)	10,550 AF (1.67 AF/acre)
Delivery allotment[3/]	19,095 AF (3.0 AF/acre)	19,095 AF (3.0 AF/acre)	19,095 AF (3.0 AF/acre)	19,095 AF (3.0 AF/acre)
Water delivery	12,352 AF (1.94 AF/acre)	12,948 AF (2.03 AF/acre)	13,499 AF (2.12 AF/acre)	9,600 AF (1.51 AF/acre)
Delivery needs[4/]	17,440 AF (2.74 AF/acre)	17,440 AF (2.74 AF/acre)	17,440 AF (2.74 AF/acre)	17,440 AF (2.74 AF/acre)
Deficit [5/]	5,072 AF	4,476 AF	3,925 AF	7,840 AF

1/ Measured with weirs and in-line flow meters.

3/ In the Hood River Basin water duties are limited to $^1/_{80}$ cfs/acre not to exceed 3.0 AF/acre per year.

4/ Calculated gross delivery needs are for full season MFID crop mix grown in the Lower Hood River Valley during an average year (1996). Gross delivery needs = weighted crop IR divided by weighted Irrigation Efficiency. Gross delivery needs include conveyance and on-farm irrigation application losses. **(See Table 16)**

5/ Deficit represents calculated full season delivery needs for an average year minus actual deliveries. Carry over soil moisture helps compensate for early season deficit irrigation most years.

IV. Existing Water Management, Measurement and Conservation Evaluation Programs

Flow measurement and water accountability are essential components of the Middle Fork Irrigation District. District staff feels they are in full compliance with Division 85 Water Measurement and Annual Reporting requirements. A Water Use Report is made annually to the Oregon Water Resources Department (OWRD). Each report includes monthly diversions for all permitted uses.

A. District Water Measuring Activities

1. MFID has rate of flow water measurement facilities at all points of diversion. Standard measuring weirs are maintained in each of the two open ditches. Glacial outbursts at the Eliot Branch diversion make weir maintenance a challenge. Downstream of the three open ditches the delivery system is a closed pipeline network, where diversion equals water used. Very high available water capacity (AWC) soils, good on-farm water management, pressure irrigation systems, deficit irrigation and high value crops have virtually eliminated over irrigation.

   Flow measurement and accounting procedures are used by MFID for determining water diversion and delivery. Sharp crested weirs and in-line meters also provide flow measurements to analyze District annual water use, including short and long-term trends.

   New and replacement flow measuring device installations should have the capability, upon installation or in the future, to electronically send a flow rate or water surface elevation signal to a common data logger/transmitter located at the MFID office. Water conservation and increased MFID staff efficiencies are anticipated benefits for upgrading flow measurement sites to include data transmission to a central location.

2. Open channel measuring devices operated and maintained by MFID staff include:

Sharp crested weirs Standard sharpcrested weirs are located where appropriate. Stream flow diverted into pipelines with flow meters

Pipeline flow meters: The MFID pipeline distribution system includes 5 flow meters. As finances permit additional flow meters will be installed.

B. Current Water Conservation Programs Sponsored by the District

District staff audits the number of sprinkler heads and nozzle size / emitters in operation by randomly selecting users annually. By counting nozzles, measuring nozzle size and discharge pressure then assisting patrons with water use summarization and assistance the district is able to maintain the most efficient means of water use.

The MFID water distribution system is designed to be an “on-demand” pressurized irrigation system. Water diversions for on-farm irrigation, temperature control, orchard spray and livestock uses are controlled by users operating on-farm valves. District staff controls the amount of water diverted for power generation. Flow rates for power production are secondary to agricultural uses.

Individual water users start, adjust and terminate water use according to their own irrigation schedule. Water transmission within the water use area is via buried pipelines. Each on-farm irrigation application varies from 50% to perhaps as high as 90% of crop water need. Moisture stored in the soil profile is used to make up the difference between crop needs and irrigation application. System efficiency has resulted in the MFID irrigation water distribution system typically running at less than 100% of capacity providing ample room for storage of water to be utilized during water shortages. To further promote conservation district staff can:

1. Encourage water users to use available irrigation scheduling tools for more practical and precise irrigation scheduling based upon available soil moisture and actual crop water need.
2. Advocate water user participation in grower organization annual meetings and seminars.
3. Help water users maintain design turnout flow rates at or below 5.6 gpm per acre.
4. Support other local groups and agencies in water conservation and management activities and programs, i.e. Hood River SWCD, NRCS, OSU Extension plus site specific water management assistance programs and measures.
5. Middle Fork ID provides technical and financial support as a member of the Hood River Watershed Group (HRWG). The HRWG identifies and procures technical and financial assistance to install water conservation and watershed improvement measures.

Middle Fork Irrigation District is cooperating with the Hood River SWCD and other groups whereby MFID staff assists in the overall irrigation water management (IWM) program in the basin by providing water use advice to small parcel operators. Suggestions are made to all users, by MFID staff, about how to use water more efficiently.

C. Collection of Runoff and Reuse

MFID water distribution is a closed pipeline "on-demand" conveyance system. On-farm irrigation decision-makers determine pipeline flows by adjusting on-farm turnout valves. Water not diverted into large diameter pipelines remains in the stream. There are no operational spills. Pipeline leaks are minimal. Sprinkler or micro irrigation systems used on-farm have no field runoff. A high percentage of the soil surface is covered with perennial, sod forming grass cover crops.

V. Goals, Concerns, and Opportunities

A. District Goals

It is recognized the pursuit of the following goals will be expensive and time consuming, however the District will actively pursue what is physically and financially realistic.

1. Long Range Goals

- Provide long range irrigation water delivery to District users, keeping within the District's authority.
  1) Meet delivery needs for irrigated lands within the District.
  2) Maintain MFID distribution capacity at 5.6 gpm/acre or more to provide adequate water delivery with internal system flexibility. On-farm consumptive use (delivery need) is expected to be 5.6 gpm per acre or less.
  3) Maintain the irrigated acreage base within the District by transferring water rights from soon to be abandoned irrigated acreage to other land. To date "change of land use" has been minimal.
- Optimize long term power generation revenue to District by:
  1) Investigating, and if feasible and environmentally sound, install additional power generation units at locations where pipeline pressure ratings are adequate and pressure reducing valves can be replaced.
  2) Where additional head is available, increase turbine operating pressure differential.
  3) Maintaining existing power generation facilities and appurtenances for long term operations.
- Maintain and improve District infrastructure
  1) Maintain long term use of each water diversion structure by repairing or rebuilding structure components having less than 25 years remaining life.

2) Maintain necessary diversion and pipeline flow records to document use for MFID water management and OWRD reports.

- For improved District water management and water conservation:
  1) Maintain limited use diversions where water can be supplied by up slope sources.
  2) Install additional pipeline flow meters where beneficial to do so. When transmitters are added, flow meters will be capable of electronic data transmission to a receiver at the MFID office.
  3) Continue to invest in remote flow meter transmitters and centralized data monitoring, processing and storage in the District office.
- Support and cooperate with public agencies and private groups working towards watershed enhancement, including fishery habitat improvement in the Upper Hood Basin.
  1) Be a technical and financial contributing member of the Hood River Watershed Group.
  2) Cooperate with resource and land management agencies; comply with the Endangered Species Act.
  3) Investigate means for Bull trout passage around Clear Branch Dam.
- Maintain the improved fish passage facilities at:
  1) Eliot Branch Diversion
  2) Coe Branch Diversion
- Through improved District water management potentially make water available for leasing to other agencies and groups. Minimum stream flows are currently maintained below pipeline diversion structures.
- Upgrade computerized equipment in the District office to receive, record, process, plot, and display rate of flow - volumetric data.

1. Short Term Goals:

- Complete Glacier Ditch pipe project. (5,400 ft 18" HDPE and 5,600 ft of 24" HDPE)
- Complete Clear Branch Dam Fish Passage Feasibility Study.
- Complete Middle Fork, HR in-stream Flow Assessment.
- Prioritize valley floor pipeline replacements needed within the next 5 years. Further identifying whether construction can be accomplished during the irrigation season or must replacement activities wait until the winter shut down period.
- Maintain District water rights.
    1) Complete water right audit using local and OWRD files.
    2) Updating property ownership in the MFID is an ongoing process. Property owner reporting of parcels sold will remain the primary source of information along with Hood River County and Title Company notices.
    3) Converting water right permits to certificates is a continuing process.
    4) Transfer water rights as available and needed to maintain District irrigated acreage base.
- Continue to install secure MFID operated turnout valves on remaining Water user shared valves.
- Cooperate with parties interested in fishery enhancement (i.e. salmon, steelhead, Bull trout, cutthroat trout, etc.) in the Hood River Basin.
- Continue working with public agencies, HRWG and private land owners to identify and implement watershed enhancement measures.
- Continue technical and financial support for the Hood River Watershed Group (HRWG) coordinator.

B. District Concerns

The Middle Fork pressurized irrigation water distribution network was a state-of-the-art system when installed and high maintenance on-farm irrigation pumps were eliminated while remaining furrow irrigated lands were converted to sprinkler. Required sprinkler system operation and maintenance costs were reduced by 80% or more. District pipeline diversions were located sufficient distances up slope to provide gravity pressure to users. Dozens of pressure-reducing valves controlled pressures. Since initial construction, several pressure-reducing valves have been added, large diameter pipelines installed, hydroelectric power generation was added and several diversions changed to limited use. Overall, the distribution system has been well maintained.

The District's ability to maintain the present level (or reduce) overhead costs is of concern. Cost of labor, materials and equipment continue to rise, as the price water users get for pears, apples, cherries and other crops rise and fall with local and foreign markets. District staff are looking for ways to reduce O & M costs by seeking out efficiencies where possible and trim other expenses.

During construction in the mid 1960's, the District assumed ownership, operation and maintenance of many miles of water user installed pipelines. These pipelines were an integral part of the District water distribution network that were also used as on-farm sprinkler irrigation mainlines. As such, most had irrigation risers spaced 50 to 120 feet apart. Initially most pipelines were installed by District staff and equipment, and paid for by neighborhood groups with USDA cost share. Prior to 1960 pipeline installations included several miles of welded steel and wood stave pipe materials, that now need replacement. Many water user turnouts have been converted to a secure MFID operated valve upstream of a second on-farm turnout valve operated by the water user.

The District is seeking ways to reduce irrigation labor costs, especially during the irrigation season. Remote distribution system monitoring and component automation has been implemented.

Glacial recession and water supply is a concern. Currently a large percentage of summer diverted flow originates from melting ice on Coe and Eliot glaciers. If these glaciers continue to recede a day will come when demand will outstrip supply. The district and other local stake holders are working together to identify other sources and opportunities for conservation to avoid problems in the future.

District staff and board members are concerned about and actively pursuing fish habitat improvement, including fish passage at in-stream irrigation diversions.

District owned and operated hydroelectric power generation facilities are aging. It will be necessary to up grade water turbines, electric control panels and other components. These costs need to be taken into account when considering long-range budgets.

MFID and an Adaptive Management Group consisting of various agencies and stakeholders developed a Fisheries Management Plan that has been approved by the U.S. Forest Service. This plan lists goals and objectives to improve fisheries habitat while maintaining the ability for the district to continue operations.

C. District Opportunities

MFID plans to pipe the Glacier Ditch with large diameter pipeline. Smaller diameter welded steel and wood stave pipelines (located in cropland areas) are currently being replaced. Extending pipelines up slope to the next higher diversion structure is complete. Improving fish passage through remaining diversion structures and reducing district labor requirements (both timing and amount) are opportunities and goals.

Installing a secure District controlled valve upstream of a water user controlled valve provides improved District administrative control and in emergencies can be used to check water releases should the user operated valve be damaged.

The MFID distribution system, being a closed pipeline system from each diversion, lends its self well to system automation. Benefits vs. cost will determine how fast the District moves in this direction, or if additional components of automation are even desirable.

D. Compare the Diversion, Supply (delivery to user) vs. Average Year On-farm Weighted Crop Water Need (Irrigation Requirement)

MFID operates an on-demand (up to system capacity) pressure pipeline delivery network, diverting water from streams on the northern slope of Mount Hood and on the valley floor. Reduced early season irrigation (diversion) requirements reflect crop use of winter carry-over moisture stored in the soil profile. District delivery rate and volume are determined by the position of water user controlled turnout valves. Actual irrigation water use is dependent upon ambient air temperature, humidity, wind speed, precipitation, and stage of crop growth.

Design MFID delivery capacity is 5.6 gpm per acre on 6376 acres. Irrigation season extends from April 15th to October 1st. OWRD assigned water duty in the Hood River Basin is 3.0 AF/year, or 19,128 AF for 6376 acres. In 2003, a high water use year, 14,262 AF were diverted.

The calculated peak period (July) irrigation requirement for fully irrigated pears using a 5" irrigation application is 0.27 acre inches per day. This converts to 143 AF/day on 6376 acres. At 5.6 gpm, required MFID system capacity is about 158 AF/day.

Table 21

AVERAGE WATER USE YEAR (2002) SUPPLY VS. AVERAGE YEAR CALCULATED CROP IRRIGATION REQUIREMENT FOR 6365 ACRES

Total Diversion [1/]	Irrigation Requirement (IR) (On-farm Crop Water Need) [2/]
13,889 AF	17,424 AF

Table 22

SUPPLY FOR HIGH WATER USE YEAR (2003) VS. AVERAGE YEAR CALCULATED CROP IRRIGATION REQUIREMENT FOR 6365 ACRES

Total Diversion [1/]	Irrigation Requirement (IR) (On-farm Crop Water Need) [2/]
14,262 AF	17,424 AF

Table 23

SUPPLY FOR A LOW WATER USE YEAR (2008) VS. AVERAGE YEAR CALCULATED CROP IRRIGATION REQUIREMENT 6365 ACRES.

Total Diversion [1/]	Irrigation Requirement (IR) (On-farm Crop Water Need) [2/]
10,550 AF	17,424 AF

1/ Composite of 11 MFID diversions. Does not include water used exclusively for power generation.

2/ Published 5 out of 10 (average) full season crop irrigation water requirement for MFID crop mix grown in the Lower Hood River Valley. Actual crop water use may vary from calculated values. Irrigation requirement (IR) includes crop water use, conveyance losses, application non-uniformity, and evaporation losses.

E. Measures to Reduce Losses

With the completion of the Glacier ditch pipeline in the spring of 2012 the only remaining open ditch conveyance in the district will be the approximately 1.0mi Eliot ditch. The piping of the Eliot ditch has been found to be economically unfeasible at this time for the following reasons.

Sediment loading would reduce conveyance capacity.

Low cost benefit ratio given the high price materials, excavation and labor.

The complexity, cumbersome nature and expense associated with projects occurring on federal property.

Operational regime of this source further limits potential benefits.

High sediment load of fine particulates provide effective sealing of channel walls virtually eliminating leakage. Occasional leaks,due to rodents, is easily and inexpensively controllable.

The MFID distribution system is an enclosed pipeline delivery network. Approximately 60 miles of pipe are used to deliver on-demand irrigation water with sufficient pressure to operate on-farm sprinkler and micro irrigation systems. Pressurized distribution pipelines located in cropland areas are buried. Pipeline leaks are minimal.

F. Studies

- In the early 1960's SCS (now NRCS) personnel completed soil intake studies to determine design irrigation application rates for sprinkler irrigation systems. Installed irrigation systems are either solid set and hand move sprinklers (>75%) or mini spray and drip (<25%) micro irrigation systems. Both systems apply water below the soil intake rate.
- Also in the 60's an Oregon State University – Soil Conservation Service study was undertaken to identify available soil water capacities in the upper Hood River Valley. Soil available water capacity (AWC) is the amount of water that can be stored in the soil available for later plant use, and is directly related to the volume of irrigation water that can be applied. Silt loam soils typically have a maximum AWC of about 1.5 to 2.0 inches per foot of depth. Laboratory tests followed by field studies over the next several years in the upper Hood River Valley confirmed a soil AWC closer to 3.5 inches per foot for Parkdale and Dee silt loam soils. Microscopic analysis identified cinder like silt sized soil particles. Each particle contained numerous holes of such a size that soil moisture was stored at a tension available for plant use. This phenomena allowed sprinkler irrigation frequencies to be extended from 7 to 10 days between irrigations to 30 days or more, providing the irrigation set was also increased from 11 ½ hours to 23 ½ hours. Lighter more frequent irrigation applications can be used to maintain lower soil moisture tensions during critical crop growth stages, i.e. bloom, pre harvest, bud set, etc.
- The District has an on-going water temperature monitoring program. Currently there are 15 temperature-monitoring sites within the district. Three of these site locations are downstream of Clear Branch Dam, upstream of Laurance Lake on Clear Branch and on Pinnacle.
- Because of the high quality data provided by the NRCS SNOTEL system, MFID utilizes the Red Hill SNOTEL site to determine seasonal water availability.

G. Flow Measurement

MFID has flow meters installed at its major points of diversion. Standard measuring weirs are maintained at the end of the remaining open canals. The majority of diversions in MFID are currently quantified by measuring devices and reported to regulatory agencies on a yearly basis. The District continues to install new flow meters and upgrade existing meters as the budget allows. As of this edition the district plans to install new electronic metering devices on all previously listed " limited use " diversions upgrading two sites per year until complete.

H. Alternatives to Finance Conservation Programs

MFID will aggressively pursue assistance and cost share funding to improve District operating efficiencies and reduce operation and maintenance costs.

Obtaining financial assistance for funding irrigation installations and demonstration measures/projects will be continued where possible, especially where Indian tribes or others provide funding for materials and the District installs the measure/project with District owned equipment and staff. Other grant money opportunities such as OWEB, OWRD, ODFW will also be pursued. MFID actively works with OWEB, USFS Title2, CTWS and Oregon DEQ in gaining "assistance and cost share funding".

Banking or pooling of saved water could be pursued where there is a potential to obtain outside funds to finance practical and feasible water conservation measures/projects.

I. Use of Conserved Water

MFID does not feel that an analysis of the potential to apply for conserved water rights is necessary as all conserved water remains in storage in order to provide sufficient supply during shortages. As the district consistently operates at a deficit of available water any expansion would not be productive.

VI. Evaluation of Potential Water Management Measures

Progress Report

All potential management or conservation measures that the District undertakes must be reasonably feasible, in all of the following categories. Documentation will be sufficiently adequate and accurate so the Board of Directors can make an accurate and justifiable decision.

Practically feasible	Can be physically constructed, resources are available.
Technically feasible	Equipment is available & affordable, meets operation and maintenance requirements.
Economically feasible	Benefit to user outweighs costs, funding is readily available, risk is acceptable to both the irrigation water user and the District.
Environmentally feasible	All existing environmental regulations can be met.

A. Energy audits for users

MFID delivers on-demand water at sufficient pressure to operate on-farm sprinkler and micro irrigation systems. There is no on-farm pumping cost to users.

B. Alternative Rate Structure

Tiered pricing of water has been considered in years past. Each time MFID board members determined multiple pricing would not be an effective water conservation tool. Costs to install additional flow meters and provide equipment and staff to monitor accounts are a concern. Grower peer pressure appears to work very well. Fruit quality is heavily dependent upon good water management. Market value can reduce substantially with very little decrease in crop quality. Both over irrigation and under irrigation can decrease fruit quality. Further analysis has not been considered warranted.

C. Re-regulation Reservoirs and Storage Tanks

Adding small regulating reservoirs (and storage tanks) within the delivery system has been investigated several times over the past 30 years. In the delivery area MFID is a closed gravity pipeline distribution system. Pipelines are designed to deliver adequate amounts of water to the lower end of laterals; therefore, benefits for internal storage are low. Emil Pond, is a small internal regulating reservoir is used as such. The installation of additional regulation or small storage reservoirs is considered unfeasible. The Volmer ditch was piped in the fall of 2008 and functions to reduce losses and increase system efficiency. The Glacier ditch will be completely piped by the spring of 2012 and further reduce losses and increase efficiency in the district. As previously described piping the Eliot ditch has been found to be economically unfeasible at this time.

D. Educational and Technical Assistance Programs

MFID fully cooperates with federal, state and local agencies to promote water conservation efforts, i.e. NRCS, FSA, OSU Extension, OWRD, Hood River SWCD, Hood River Watershed Group (HRWG), etc. District newsletters encourage users to consider benefits of other cost share programs, i. e. USDA EQUIP, etc. MFID provides technical and financial assistance to the HRWG, organized to coordinate watershed enhancement projects.

The District provides direct assistance to water users for improving irrigation efficiency. Because MFID is an on-demand, deficit irrigation delivery system, providing irrigation scheduling assistance to users is not practical at this time. MFID growers market fresh packed pears, apples and sweet cherries world-wide. Quality (and quantity) has been a long standing goal. The District provides a nozzle and gasket “buy back’ program through it’s news letter. The district will reimburse patrons for the cost of purchasing new nozzles and gaskets when presented with the invoice and the old worn out equipment.

E. Sharing of Water

The MFID water distribution system has not been designed to accommodate the flow rates that would allow it to convey water to neighboring districts thereby making water sharing arrangements impractical.

Consideration was once given to providing pressurized irrigation water to the Dee Irrigation District (~1200 acres) from Middle Fork Hood River sources. Over five miles of Dee Irrigation District open ditch and a diversion on the West Fork of Hood River would be abandoned. West Fork Hood River fisheries will benefit by diversion abandonment and increased summer flow rates. The estimated high cost of needed infrastructure and the need to arrive at a common solution among regulatory agencies were insurmountable hurdles for completion.

Although MFID water users can share water with each other on the same District lateral the need to do so has been very limited. Good irrigation water management, a District design delivery capacity of 5.6 gpm, very high AWC soils and a potential 15 - 30 day or longer irrigation frequency all contribute to individual farm self sufficiency.

F. Flexibility of Water Delivery

The District now operates a fully "on-demand" type delivery system, in accordance with project design. The position of on-farm water user controlled turnout valves determines MFID delivery rate and volume. The District is currently operating at a fairly high management level. No increase in water savings would be expected by changing delivery methodology.

G. Retirement of Irrigated Lands, Water Pricing, Water Rate Structure

An analysis will be provided to determine potential water savings benefits due to changing water pricing, water rate structure and retirement of lands in the District. For many reasons, it is felt retirement of irrigated lands within the District is not a viable option, at least in the near future. At this time, maintaining a viable irrigation District for continued distribution of water is deemed essential. An analysis of pricing structure has been found to be unwarranted for the following reasons. Given the very low percent of losses through the piped system and the fact that the district operates at a water deficit given the irrigation water demand of crops, rate structure incentives are not practical and the district finds that the sprinkler nozzle and gasket program is more effective at encouraging the application of water in the most efficient manner.

Available irrigation water and good on-farm irrigation water management are essential for maintaining quality crop growth and yield. Fruit trees and other crops would suffer irreparable damage if irrigation water were removed during hot, low precipitation summer months. Conversion to non irrigated farming techniques is not realistic as yields and quality would plummet and the market for Hood River Valley fruit would evaporate.

Water pricing (base price) for MFID water in 2011 was $25 up to the first acre plus $12 per acre over one acre, for delivery up to 3.0 acre feet/acre irrigated. This charge includes system operation and maintenance plus District administrative costs. Power revenues cover over 90% of District costs most years. The board reviews costs and revenues at least annually and makes budgetary adjustments supporting water conservation through reducing transmission losses such as piping open ditches. The board of directors elected to reduce staffing levels as a means of controlling expenses while power rates were depressed and as such eliminated one full time position. The District feels this approach is more appropriate then raising user rates and placing further financial burdens on already overtaxed and overregulated family farms.

H. Conversion to Metered and Pressurized Deliveries to Small Land Parcels

To date (NOV 2011) conversion of irrigated land to small parcels has been very limited. The district remains informed of partitions and development through the county planning process. The District reviews all new developments within the District during the planning process and works with developers to ensure that water rights are maintained per MFID policy and state water law. The district does not require meters based on parcel size.

I. New Storage Reservoirs

Planning for or implementing new storage reservoirs is a challenge at this time. The district is aware of a dedicated amount of winter water reserved in the East Fork above Dog River. This water is reserved for “multi use” and could provide a new source of water to supplement summer stream flows for environmental reasons. Cost and feasibility are unknown at this time. The district is participating in a county wide water planning process that will look into this in the coming months and years.

J. Conversion from Surface to Sprinkler or Micro Irrigation Systems

There are no surface irrigated lands in the Middle Fork Irrigation District. All lands are irrigated with sprinkler or micro irrigation systems.

K. Remote Monitoring and Control

A remote monitoring system is being utilized by MFID. The system includes remote monitoring of flow rates and water levels as well as temperature. A radio base station and dedicated computer are located in the MFID office to receive process and store data received from external weirs and flow meters. MFID staff can access near real time data over the internet or stored data via office computer or a laptop computer. This system has reduced O&M expense somewhat. The District continues to install monitoring equipment in locations that are appropriate and beneficial.

VII. Drought Contingency Plan, Curtailment and Allocation Procedures

Upon the Declaration of a "Severe, Continuing Drought" by the Governor the District will enact and adhere to all rules described in ORS690 Div.19

Concerning the "Powerdale Issue"
The process of converting an existing water right to an instream water right is a function of Oregon Statutory Law. The Powerdale water right conversion is an inchoate legal proceeding and should not be speculated upon in a conservation plan. Middlefork Irrigation District will participate in any public process that affects water rights held by the district.

A. Drought History and Assessment of Vulnerability

The Middle Fork Irrigation District (the "District") diverts water from 10 small streams located on the northern slope of Mount Hood and on the valley floor. In addition, Clear Branch Dam (Laurance Lake) stores runoff from Pinnacle Creek and Clear Branch. Except in low water runoff years, watershed yields are generally adequate.

Frequency, duration, severity, shortage of supplies, potential for catastrophic loss of water

With the construction and operation of Clear Branch Dam and reservoir (Laurance Lake) and with installation of the many miles of pipeline in the District, the potential for water supply deficiencies (as occurred in 1974) has been substantially reduced. Laurance Lake acts as both a storage and regulation reservoir. Very low water supply years have occurred once in the last 31 years (1973 – 2004). During low water supply years, delivery to users is reduced equally. Reduced crop yields and quality result. With only one year's storage for a small portion of the District available in Laurance Lake, good distribution system water management is required on a continual basis.

When (1) Clear Branch and Pinnacle Creek runoff is less than adequate to refill Laurance Lake, (2) summer watershed yields are below average, and (3) higher than normal summer delivery requirements are present, a potential very low water supply year or "drought" condition is pending.

Before Clear Branch Dam was constructed, less than adequate water deliveries occurred almost every year, primarily due to poor water quality not water quantity. During hot summer months the very high glacial sand (glacial flour) content in water diverted from Coe Branch and Eliot Branch (Creeks) was extremely abrasive. Glacial sands are highly abrasive flake-shaped rock chips resulting from glacier movement of rock on rock. During hot summer weather Coe and Eliot glaciers recede; exposing steep, highly erosive banks containing glacial sand (rock chips) plus other sand, silt, and clay particles. Wet-dry and freeze-thaw cycles provide a constant glacial sand yield into an otherwise clear water source. Sprinkler irrigation nozzles would wear out several times per season. Often the decision: water quantity vs. water quality had to be made several times each day. Deficit delivery still exists, but not as bad as it did before.

The District relies on both natural stream flow and storage in Laurance Lake for the irrigation water supply. Managing these two sources together provides some intra District flexibility. During hot summer months, Use of Coe and Eliot Branch waters can be temporarily discontinued when water quality is poor.

During the extreme drought year of 1974, water users were put on rotation deliveries. Rotational deliveries were last employed in the lesser drought year of 1979. Delivery in 1974 was approximately 80% of an average water supply year (2002 being regarded as an average year). Water was delivered uniformly at the same percentage to everyone served by each District lateral. Water availability at a point of diversion, via stream flow or canal, controlled deliveries rather than water right priority date among diversions or users.

Irrigation water delivery during 1974 and 1979 was very stressful on District staff due to demands by the users. All users wanted their share of water delivered, because the effect on them was economic, i.e. limited water meant reduced crop quality and yield resulting in reduced income.

To be alert to indicators of drought, the District keeps itself informed about the current snow pack and precipitation in the upper Hood River watershed using the NRCS "Red Hill "SNOTEL site located approximately 1.3 miles west and 1400 ft in elevation above Laurence lake.

<u>Delivery during low water supply years</u>

When reduced stream flow limits water availability, on-farm deliveries served by the district are decreased uniformly and, if stream flow is severely reduced, the District implements rotation deliveries. The District reserves the right at any time of low water to curtail deliveries as necessary in accordance with a share the pain philosophy, as outlined in Part E below. Some users can choose an early shut off in the season in lieu of reduced deliveries. As early in the growing season as it can, the District's Board of Directors (the "Board") alerts growers of the potential for reducing deliveries from on-demand to volunteer reduced demand, then to rotation. Typically any change is initiated midway through the irrigation season. Some sharing of water between users on the same lateral exists. Moving water to distant lands by using temporary cross over pipelines is not a reasonable solution and in some cases not legal.

The self-imposed target stream flow downstream from any valley diversion structure is one cfs with no less than one-half cfs at any time.

Vandalism

Vandalism to existing water control structures and/or water supply, or accidental contamination of the water supply could potentially occur. Depending on magnitude, severe water shortages could result. Vandalism or water contamination has not occurred in the past. Security appears to be adequate to limit vandalism. Public access to Laurance Lake (including visual observation of Clear Branch Dam) and at least daily visits by District staff have been sufficient to ward off serious vandalism. If a condition occurred where storage or stream flow was lost or partially lost, curtailment and allotment procedures would be followed, as outlined in Part E.

Major diversion structure and open ditch failures due to natural disasters have and will occur in the future. Major vandalism and/or or accidental contamination of water supply could potentially occur in the future. Glacial outbursts above Coe and Eliot Branch diversions disrupt flows about once every five to ten years. Any of these types of events, depending on severity, could create a water shortage for that portion of the District served by the facility affected. Major vandalism and/or contamination of water supply have not happened in the past 30 years. District facilities are well maintained and sufficiently secure.

Exposed low elevation reinforced concrete diversion structures would require heavy construction equipment or explosives to render them nonfunctional. If such a thing (major structural failure, severe vandalism or contamination) occurred, that portion of the District affected would go on curtailment and allotment procedures as outlined in Subpart E, until repairs could be made.

Natural events

Extensive flooding due to excessive runoff from snowmelt or precipitation and glacial outburst events can cause damage to diversion and distribution structures. Should such an event occur during the growing season, temporary curtailment of water delivery would be implemented for users receiving water from that part of the system. As witnessed in November 2006, the buried pipeline distribution system itself can be damaged. These storms can occur any time of year, whether from rainfall, snowmelt, or severe spring and summer precipitation events. In the November 2006 debris flow, the Eliot creek diversion was completely destroyed and 1600 ft of 36 in pipeline was damaged. Coe Branch and Eliot Branch diversions may not be functional for several weeks during summer months due to poor water quality. District infrastructure is sufficiently flexible that water deliveries can continue if small limited use diversions are damaged, significant damage to the major points of diversion would result in curtailment of deliveries until repairs could be made.

B. Planning for Drought

Irrigation District managers in the area communicate often during each irrigation season to review current issues pertaining to irrigation water, i.e. supply, diversion, snow survey and runoff forecast data, flow records, pending rules, etc.

There are no cooperative agreements with other water suppliers. The Upper Hood River Valley domestic water supply system has insufficient capacity to be of value to the irrigator. Other irrigation Districts are located down slope and would have similar flow restrictions.

Water supply projections – USDA/NRCS and US Weather Service provides public forecast information for potential runoff from January through early spring months in all river basins in Oregon. This information is readily available on computer internet web sites for USGS, NRCS and US Weather Service.

A hot, dry summer may not follow a low snow pack runoff period. Significant early growing season plant water can be provided by spring precipitation events and winter carry over soil moisture. Early growing season precipitation and temperatures also affect both timing and amount of crop water need. Ordinarily the heavy demand for irrigation water in the MFID begins in late June or early July.

Past Drought Mitigation Procedures

Severe water delivery restriction occurred in 1974 and to a lesser degree through the 1979 irrigation season. As with all low water supply years, on-demand water delivery is changed first to voluntary reduction then to a rotational system, typically about mid way through the irrigation season. Water delivery was provided uniformly to all users being served by each District lateral.

Operational and management spills, used for fisheries and stream corridor aesthetics, were reduced substantially during low water years. Reduced spills required more intensive water distribution system management. During low water years seepage losses in open conveyance facilities can not be eliminated, thus conveyance losses are higher percentage wise than for normal years. As of this revision the District is near completion of pipe projects that will eliminate all conveyance. All users were asked to limit irrigation water uses. In each low water period extra time and effort are spent by District staff to provide more precise water distribution system management, resulting in increased operation cost to the District.

C. Triggers

The following watershed triggers will be used to identify drought conditions:

- **Heads Up**

NRCS reports snow pack on April 1st is less than 60% of average, Coe or Eliot Brach Diversion is inoperable and a low Hood River stream flow is forecast. The District Manager via newspaper articles, direct mailing, newsletter or personal contact provides a "heads up" in early May to alert irrigation water users of the potential for reduced water deliveries. Hydro production could be curtailed to insure that Laurence lake is full.

- **This is Serious**

Laurance Lake fails to refill by May 1st and snow pack is less than 50% of average and a low Hood River stream flow is forecast. Clear Branch and Pinnacle Creek snow pack runoff (watershed yield) into Laurance Lake is perhaps the earliest physical evidence that there could be a limited growing season water supply. Typically, runoff is more than adequate to fill the reservoir to capacity except in very dry years. Timing and amount of runoff varies from year to year. Should the above trigger occur, the Board via newspaper articles and direct mail will announce a District water users meeting to present and discuss current water supply conditions. Staff will present estimated Coe Branch, Eliot Branch, Pinnacle Creek and Clear Creek runoff potential plus Laurance Lake storage. Potential curtailment and allotment procedures are discussed and an alert issued.

- **It's a Drought**

Watershed snow pack on June 1st is less than 60% of average, Laurance Lake storage is less than 2,500 acre feet and a low Hood River stream flow is forecast. Spring precipitation and cool temperatures may reduce the early growing season crop irrigation water requirement (IR). Typically spring precipitation also increases watershed runoff, which increases reservoir inflows. Either action helps negate potential drought conditions. Though possible, it is not probable that spring weather conditions will salvage a predictable drought condition. When the above trigger occurs, the Board will consider implementation of selected curtailment and allotment procedures, i.e. voluntary reduced deliveries, and if severe, delivery rotation.

Other factors that may affect extent of curtailment activities include:

1. Drought condition determination

NRCS and US Weather Service provide public forecast information for potential runoff from January through early spring months in all river basins in Oregon. The District cooperates closely with NRCS to help maintain awareness of current snow pack conditions in the upper Hood River watershed. District staff can poll individual NRCS SNOTEL sites. Storage information is available on a continuing basis through (1) the SNOTEL system, and (2) on-site visits. Current runoff projections are accessed via interagency websites.

2. Drought condition indices

The following indices, trends, reports, etc. are used by District decision-makers to identify current and pending drought conditions:

- Published NRCS SNOTEL data and runoff projection. See the NRCS Snow Survey Products website at http//crystal.or.nrcs.usda.gov/snowsurveys/ Click on Data, then on Oregon/Washington Snow Survey Products – WSOR for Oregon to select current snow survey information.
- Individual NRCS SNOTEL site readings interrogated by District staff, i.e. Red Hill.
- Published Oregon Weather Summary, Oregon Climate Service, Oregon State University (10 day lag time). Also available on the Oregon climate Service website at http://www.ocs.orst.edu
- Published NOAA Climatalogical Data (month lag time).
- Burn Index.

3. Drought condition modification

Variations in weather patterns may correct a drought situation before it becomes critical, i.e. above normal spring and early summer precipitation and lower than normal temperatures may alleviate the effect of a dry winter. There is no way to accurately predict the weather.

At any time in the spring or early summer, should a potential drought condition change to what shows to be a more normal water supply year, the same communication procedures that were followed to initiate action will be used to cancel or modify action.

D. Courses of Action

1. District Courses of Action

When the following local conditions exist District action will be:

Limited watershed yield resulting in reduced irrigation water diversion.

(For example: a hydrologic burst upstream of the Eliot Branch diversion.)

1. An evaluation of watershed conditions is made by District staff, the Board, consultants, etc. as needed to:

- Identify temporary structural modifications that can be made at diversions and in the system to limit the effect of a reduced flow rate.
- Design temporary (or permanent) modifications as needed to return the component or facility to a fully operational status. For example: construct earth wing dams < 50 cubic yards, extend reinforced concrete wing walls, install new toe (cutoff) walls, etc.
- Design permanent modifications to return the component or facility to a fully operational status.

2. Evaluation personnel identify modification alternatives, costs, and required construction time (for each alternative).

3. The Board selects which alternative(s) are to be implemented, including: source of funding, implementation (contract, force account, District staff and equipment, etc.), and construction time allowed for completion of the required work. Along with the alternative(s) selected, the Board identifies whether repairs are temporary or permanent; and if temporary, when is permanent follow up work scheduled.

4. The Board identifies reduced water delivery actions to be implemented by staff.

Component failure resulting in reduced irrigation water diversion.

1. An evaluation of the structural failure is made by District staff, the Board, equipment and material suppliers, consultants, etc. as needed to:

• Determine, if possible, the cause of failure.

• Identify temporary (or permanent) repairs needed to return the component or facility to service until winter shutdown.

• Design permanent repairs to return the component or facility to a fully operational status.

2. Evaluation personnel identify repair alternatives, costs, and required construction time (for each alternative).

3. The Board will select which alternative(s) are to be implemented, including: source of funding, implementation (contract, force account, District staff and equipment, etc.) and construction time allowed for completion of the required work. Along with the alternative(s) selected, the Board identifies whether repairs are temporary or permanent; and if temporary, when is permanent follow up work scheduled?

4. The Board identifies reduced water delivery actions to be implemented by staff.

2. Community Courses of Action

When a drought is imminent community action will be:

• The District Manager contacts the Hood River County Commissioners, the Hood River Valley SWCD and appropriate local, state and federal agencies to cooperatively assess the conditions based on accumulated low elevation winter precipitation, existing reservoir storage, and projected runoff. When drought conditions are viewed as a real issue, Hood River County officials then request from the Governor a declaration that official drought conditions exist.

• The Oregon Drought Council (representatives from state and federal agencies, and the Governors office) meet to assess the drought declaration request and local conditions. This group makes recommendations to the State Emergency Management Group, (503) 378-2911. The State Emergency Management Group provides a recommendation to the Governor. The Governor officially declares the specific county or region as a Drought Area.

• The District is then allowed to use any of the drought mitigation tools available under state statutes and administrative rules, which tools are currently found in ORS 536.700 to 536.780 and OAR 690-19. A drought declaration also helps users qualify for federal relief funds, etc.

3. Discussion

Alternative sources of water and/or point of diversion transfers are not currently available to the District. The District is the most upstream irrigation District in the Hood River basin. Significant quantities of well water can not be purchased.

Diversion of water from other basins is neither feasible nor practical. When drought conditions exist, winter precipitation and runoff in adjacent basins are very closely related, therefore would also be short of water. Because of topography and distance, water diversion from other basins would be very expensive.

A possible alternative would be to establish a temporary (or even permanent) water delivery process during drought years that would provide some users the opportunity to voluntarily accept less or no water, and pay less. Thus allowing other users, with more critical irrigation water requirements, to be supplied more water but pay a higher rate. A detailed analysis of establishing such an alternative, or modification, would have to include all impacts on legal issues, contracts, additional administrative duties, operation and management of water delivery, effects on budget, etc. Official action of the Board would not be taken on the establishment of this alternative until all issues were resolved and accepted by the Board. A vote by water users may be required. This course of action cannot be resolved at this time, but may be evaluated in the future.

Using groundwater, as a supplemental irrigation water source during drought conditions is always a consideration. However, determining well location(s) and obtaining legal use of water, even for emergencies, would be a very time consuming action involving OWRD water right applications. Based on past well drilling experience, sufficient quantities of water may not be available at economical drilling depths. Cost of well, pump and pipeline operation and maintenance is also a consideration.

E. Curtailment and Allocation Plan Implementation

Curtailment Procedures

Based on the projected water supply and recommendations of District staff, the Board provides the final decision and direction for allocation of water during and following each curtailment event. Degree of curtailment and allocation to users will be based on the projected water supply reduction, Considerations include:

1. Stage of crop growth
2. Soil moisture condition
3. Percent of growing season
4. Amount of water available

Curtailment procedures that will be followed during low water supply (drought) years include:

- Water delivery to farm turnouts on affected laterals will be uniformly curtailed in proportion to the volume of water available. The primary curtailment activity is, and will continue to be, reducing on-farm application rates. Application rates can be reduced by (1) reducing the number of on-farm sprinkler and micro irrigation laterals operating at one time, and (2) using smaller irrigation nozzles in all laterals. Typically full line pressure is provided by the District.
- Delay water turn-on date for water stored in Laurance Lake to conserve water for (1) critical crop growth periods, (2) peak period consumptive use, and (3) to help meet projected total season water needs vs. projected water availability.
- Provide intensive management and control of all water within the District.
- When necessary, decrease hydro production.

• Provide practical, comprehensive information to irrigation decision makers to help reduce on-farm water use.

• Encourage landowners to keep grass cover crops short by frequent mowing.

• Cooperate with local, state and federal agencies providing assistance to irrigators on how to optimize on-farm water use.

• Evaluate the potential for providing financial incentives to users for reduced delivery, based on availability of funding.

• Evaluate potential for non-District cost share funding for implementing temporary or permanent on-farm water conservation measures i.e. installation of flow meters, smaller sprinkler nozzles, etc.

• Provide a comprehensive weekly analysis of water availability, with water use goals set week-by-week.

Allocation Procedures

• Stream flow plus Laurance Lake storage will be delivered to irrigated lands according to availability with a "Share the Pain" process.

• With District approval, individual water users can voluntarily:

a) Reduce the amount of water applied per acre by decreasing irrigation set time, thus allowing near normal operation of sprinkler and micro irrigation laterals, including irrigation frequency (days between irrigations).

b) Reduce nozzle (or emitter) size on all on-farm irrigation laterals, thus allowing near normal operation.

c) Reduce irrigated acres until repairs can be made or the water supply improves.

d) Share available water with other users having more critical water needs.

e) Not irrigate during low water supply periods in lieu of a receiving a higher priority for water later in the irrigation season, to the extent feasible.

VIII Legal / Institutional / Environmental Considerations

A. Legal Considerations

The Middle Fork Irrigation District obtains water from public waters of the State of Oregon via 10 in-stream diversion structures and two streams entering a reservoir. Water is delivered for irrigation, hydropower, temperature control, orchard and cropland spraying plus fire and livestock purposes. The Middle Fork Irrigation District is a legal subdivision of the State of Oregon. MFID operations comply with applicable Oregon Revised Statutes and Oregon Administrative Rules. Necessary permits and/or water rights are current.

B. Institutional Considerations

The Middle Fork Irrigation District is a public utility formed for the purpose of obtaining and delivering irrigation water to users. Electric power revenues generated at three MFID owned hydropower stations help off set water delivery costs.

C. Environmental Considerations

The MFID distribution system is a closed pipeline system. Water is diverted from natural streams into pipelines at locations throughout the District. Where water is available in the system or from streams up slope, pipelines have been extended to the next higher diversion structure to limit the use of some diversions, thus reducing O&M and improving fish passage. Improving fish passage through remaining diversion structures and reducing District O & M requirements (both timing and amount) are being pursued and implemented.

1. Issues

MFID is committed to sound economic and environmental practices. When the hydroelectric operation was planned, the following measures were proposed to mitigate any adverse effect of the construction and operation of the project. (1) Renegotiation of minimum stream flows in Clear Branch below the dam. (2) Confining penstock routes to existing irrigation pipeline rights-of-way or to corridors already occupied by public roadways. The project used historical diversion points on three streams. (3) Powerhouses were located adjacent to existing irrigation system facilities and designed to minimize local impacts. (4) Powerhouses were located adjacent to or within a few hundred feet of existing power lines. (5) There was no change in public access with the exception of a small area around each powerhouse fenced for public safety.

2. Fisheries

Rainbow trout, cutthroat trout and Bull trout.

It is currently known that Clear Branch, Laurance Lake, Pinnacle Creek and Compass Creek have been identified as some of the only areas with Bull trout, Salvelinus confluentus on the Mount Hood National Forest. Salvelinus confluentus (Bull trout) are listed as a Threatened species under the Endangered Species Act. Laurence lake and much of the Middle Fork Hood River drainage has been designated critical habitat for Bull trout. MFID has been involved with the following activities in order to assist with the conservation of the population of Bull trout in the watershed.

Fish Trap. The fish trap immediately downstream of Clear Branch Dam was completed in September 1996 with USFS cost share. MFID contributed $25,000, water to run the trap, ongoing labor for maintenance and checking trap and use of the site. 1997 was the first full season of use for the fish trap and 7 Bull trout were caught and tagged and approximately 120 other fish e.g., Rainbows and cutthroats. This fish trap provides the ability to count, tag, and collect data on various salmonid species (rainbows, cutthroats, cutt bow hybrids and Bull trout). The trap will also allow a trap and haul program to boost upstream stocks of Bull trout and possibly other species. For unknown reasons the efficiency of the trap has been dropping off. Increased river otter population is suspect.

Spawning Gravel. MFID in cooperation with the USFS and ODFW has added washed round rock immediately below clear Branch Dam for spawning gravel. The gravel is creating spawning areas that have not existed for 25 years due to blockage of gravel recruitment by the dam. USFS pebble counts in the stream verify the additional spawning habitat.

Monitoring Fish Population. MFID personnel have and are currently working with ODFW and the USFS to monitor the population of Bull trout in Laurance Lake, Clear Branch above and below the reservoir, Pinnacle Creek, and Compass Creek. MFID routinely participates with fisheries personnel working in the basin.

Fish Ladders and Screening. MFID has converted to limited use diversions or has removed passage barriers altogether at many of its diversion sites. Passage has been reestablished at the Coe and Eliot diversions, as of this writing the district is engaged in a passage feasibility and screening study for Laurence lake. This study is in cooperation with Oregon Department Fish and Wildlife (ODFW) Confederated Tribes of the Warm Springs Reservation (CTWS) US NOAA Fisheries Service (USNFS) US Fish and Wildlife Service (USFWS) and private engineers and consultants. Study results are expected to be available in early 2012.

Rehabilitation/Revegetation Project. Eight tenths of an acre immediately below Clear Branch dam was rehabilitated to help control erosion and eliminate sediments entering Clear Branch and ultimately the Middle Fork of the Hood River. Eventually, the stream in that area will be shaded and large woody debris will be contributed to the stream due to this project. 100 Tons of wood by product was spread over the site. Seven native grasses and seven native plant species were seeded over the wood fiber and have established. Cuttings from six local riparian shrub species and 40 cedars were planted along the stream bank and have taken root. The USFS provided the erosion netting and planted 1000 coniferous trees across the site. A crew from the NW Service Academy was hired to help with the project.

Stream flow evaluation.

The District is in the early stages of commissioning an in stream flow study in the reaches below its points of diversion and the Middle Fork Hood river. This study is in cooperation and or assistance with ODFW NOAA USFS, USFWS CTWS. The study results will be used by decision makers to better plan and implement projects designed to restore habitat and insure the long term viability of the district

3. On-farm Activities

On-farm irrigation application systems are either sprinkler or micro. Good on-farm water management, permanent grass cover crops, high AWC soils, cost of irrigating and deficit irrigation through out the growing season helps eliminate field runoff. Should excessive leaks or field runoff be observed (or reported) District staff close an upstream valve until the problem is corrected.

Pesticides are used on-farm to control undesirable insects, fungi, bacteria, etc. Overall cost of materials, cost of field application, and general concern for the environment (including health and safety of workers) dictates good pesticide management. Tractor pulled spray machines are used to apply pesticides according to label for efficient material application and to minimize on-farm liability.

A permanent grass cover crop is maintained in orchard areas to reduce soil erosion, improve soil condition, and minimize dust due to farming operations. Typical tree canopy in a mature orchard varies from 90 to 100% closed. Deer and elk are commonly observed. Small animals and birds are also present.

D. Environmental Evaluation

Environmental and resource concerns pertaining to the operation, maintenance and project activities within the MFID have been addressed in the recently completed MFID Fisheries management plan. This plan was collaboratively developed by the district and agency stake holders to address issues associated with the district operation. It is intended as a road map for the district for future studies and projects that will lead to improved aquatic conditions and long term success of the district.

Soil Erosion

There will be no negative impact to soil resources due to long term movement of soil from precipitation, sprinkler and micro irrigation sources, primarily due to permanent cover cropping, high AWC soils, and deficit irrigation. In orchard areas a high percentage of the soil surface is protected by a permanent grass cover crop. Dust suppression and soil trafficability are also improved. Non-irrigated areas are covered with native grasses, shrubs and trees. There is no dry cropland in MFID.

Unprotected concentrated flow areas in orchards and fields are not apparent. Classic gullies will not result from anticipated District O & M or project activities. Water is applied at rates that do not cause ponding or excessive runoff thus will not cause impairment to soil resources. There are no soil mass movement sites in the project area or are any expected. Excess erosion from road banks and scour areas are not apparent in the project area or are expected.

Water Quantity - General

There will be no reduction in crop production and soil trafficability on adjacent croplands. Slope stability along pipelines, and concentrated flows from storm runoff will not change appreciably.

In MFID irrigation water is applied in the amount and at times that provide for optimum crop water use, does not impair crop growth or cause excessive runoff. A district wide seasonal irrigation efficiency, estimated to be greater than 90 %, indicates on-farm evaporation, surface runoff and/or deep percolation are very low. Conveyance capacities of drainage ditches, road ditches, culverts etc. will not be impaired due to MFID operation, maintenance or project activity. Elevated water temperatures in Laurence Lake and downstream of Clear Branch Dam are of general concern.

When a significant on-farm pipeline leak is discovered, or reported by others, District staff or water users discontinue water delivery to the affected area by closing a turnout valve.

Water Quality - Ground Water Contaminants

Pesticides, nutrients & organics are applied at rates and times to avoid excessive leachate occurring below the plant root zone. The existing District wide on-farm seasonal irrigation efficiency indicates that very little deep percolation occurs. Only sprinkler or micro irrigation systems are used in the MFID, with deficit irrigation practiced through out the growing season. There are no known excessive salt, heavy metal or pathogen concerns in the area.

Water Quality - Surface Water Contaminants

Due to permanent cover cropping, deficit irrigation and low sprinkler or micro application rates, surface runoff from fields due to irrigation is nonexistent. On-farm pesticides are mixed in designated areas, far removed from any flowing stream and applied according to label. Native riparian buffer strips are maintained along streams.

Air Quality

No long term air quality impairment pertaining to property or personnel safety and health will result from District O & M or project activities.

Animal Habitat, Food and Shelter

Wildlife

Overall, wildlife habitat is increased by irrigation activities. Food, cover and water for certain species of wildlife may be slightly negatively impacted (short term) during site specific construction activities. However, the percent of total area affected is extremely small. Natural habitat regenerates very rapidly, especially in boundary areas receiving sprinkler irrigation over spray. Food and cover for certain wildlife species are available along property lines, rights of way, and non-cropland areas since these areas are not farmed.

Domestic

No negative effects are expected for food, cover/shelter, and water for domestic animals.

Animal Management

Wildlife

Population/resource balance and animal health is expected to be maintained, as there will be no negative impact.

Domestic

Population/resource balance and animal health is expected to be maintained, as there will be no negative impact.

Cultural Resources

No cultural resource activities have been encountered in the immediate area in the past due to project installations on MFID rights-of-way, or farming activities on the adjacent fields.

Conclusion: There will be no negative impact to cultural resources due to operating and maintaining project installations.

E. Environmental and Public Considerations

- Threatened & Endangered Fish species – Bull trout, winter steelhead, Coho Salmon
- Natural Areas -The Middle Fork Irrigation District includes approximately 30% native vegetation areas. These areas have never been modified due to steep slopes, shallow or rocky soils and vegetation. Upland game birds, plus small to large animals use native vegetation areas for food, shelter and cover.
- Visual Resources - The Middle Fork Irrigation District includes approximately 30% native vegetation, non-agricultural areas. The balance, primarily orchard areas, appears green throughout the growing season, a definite visual enhancement. People travel for miles to observe the grandeur of fruit tree bloom lasting several weeks in April and May. Thousands travel to the Upper Hood River Valley year around to view Mount Hood with orchards in the foreground.
- Flood Plain - There are no major flood plain areas occupied by homes or cropland in the Middle Fork Irrigation District. East Fork Hood River, Middle Fork Hood River, Evans Creek, Rogers Creek, etc. are deeply incised streams having steep side slopes covered with native trees and brush.
- Wetland - Identified wetlands within MFID are typically less than an acre in size, located on-farm in nearly level swales.
- Riparian Area - Riparian area vegetation is unaffected by MFID activities.
- Prime, Unique or Important Farmland - Soils immediately adjacent to MFID project facilities are Capability Class II - VII. There will be no effect on these soils due to MFID activity.
- Degree of public interest/potential controversy - District operation, maintenance and anticipated project activities are not major federal actions that will have significant effect on the quality of human environment. Operation, maintenance and project activities will be entirely on Middle Fork Irrigation District rights-of-way.

MFID Project actions and Operation & Maintenance activities would not:

- Have a significant effect on the quality of human environment.
- Involve unresolved conflicts concerning alternative uses of available resources. (Cooperative project planning typically resolves conflict.)
- Have significant effects on public health or safety.
- Affect properties listed as eligible to be listed in the National Register of Historic Places.

IX. Long Range Supply

During average or better water supply years existing water supplies can meet users delivery needs, however only with good District and on-farm water management. Good District water management includes proper operation and maintenance of in-stream diversions and Clear Branch Dam. On-farm water management practices include timing irrigation applications such that (1) winter carry-over soil moisture is used to the fullest extent possible, and (2) the affects of deficit irrigating on crop quality and quantity is minimized.

Should the District face drastic cutbacks, due to any reason, the needs of the District water user will suffer. Many issues that impact the Hood River Basin also directly impact MFID. Thus, it is important to optimize available water, i.e. storing winter runoff in Laurance Lake for irrigation season use and utilization of winter carry-over soil moisture.

A. Projection of Water Demand in 20 years

1. **Issues Affecting Future Water Demand are:**

a. Future agriculture water needs may be reduced:

- By cooler and wetter climate, affecting cropping pattern changes and water needs.
- Greater utilization of micro irrigation application methods.

b. Future agricultural water needs may be increased by:

- Warmer and dryer climate affecting crop water needs.
- Decreased flow contribution from glaciers due to climate warming.
- Increasing MFID system capacity to provide more water per irrigated acre, thus reducing deficit irrigation.

c. District piping projects have reduced transmission losses and improved water quality, allowing irrigators to utilize more efficient micro style applicators. This reduced demand helps to balance the deficit condition of irrigating within the district. Future piping projects will help to reduce this condition even further. Winter flows in the East fork Hood river identified for multiple uses present an opportunity for an additional supply of irrigation water. Preliminary investigations into utilizing these flows revealed the need for construction of conveyances and storage infrastructure. The district continues to consider these options as time and budgetary limitations allow. No speculation as to when this supply might be needed has been made. A benefit/cost analysis of the feasibility of utilizing this source as an additional supply would require an exhaustive study including surveying, permitting on federal lands, construction costs, land acquisition and development of a climate model to predict hydrologic conditions 20yrs in the future. The district currently directs available funds toward improving the existing system and reducing transmission losses. Hood River County has applied for a grant to study the feasibility of utilizing the available East fork water. Middle Fork Irrigation District operates in a confined valley with a small and efficient staff of dedicated employees. The district works with the other districts and stakeholders within the Hood River Valley on topics of conservation through local planning and cooperative working groups such as the watershed group. The district strives to maintain amiable working relationships with all stakeholders in the watershed.

d. Orchardists within the district remain abreast of trends in the fruit growing industry and utilize best management practices to maintain a sustainable harvest of quality fruit for the Oregon economy. What happens "on farm" with respect to crops and rotation trends concerns the district only in so much as irrigation water is applied beneficially without waste.

e. **Comparison of water needs with size and reliability of water right**: As has been noted throughout this Water Management and Conservation Plan MFID operates within a water deficit condition and is continually making system improvements to operate within it's allowable water rights in a more efficient manner and provide surface flows for a healthy, sustainable watershed. MFID remains ready, willing and able to utilize its full portfolio of water rights for beneficial uses while working with regulatory agencies to identify and provide for the needs of threatened and endangered species. The greatest threat to the reliability of Hood River water supply is climate change. Recent studies by OSU have found that late season flows in the Hood River will be reduced and as such pose a threat to available water rights be fully utilized.

2. Demographic Changes

The upper Hood River Valley remains largely defined by agriculture no significant changes have occurred in recent years that have resulted in urbanization or reduction of parcel sizes. To date fracturing of larger farms within MFID has been very limited. Delivery of irrigation water to many smaller parcels is generally less efficient and at higher cost than to fewer larger agricultural parcels. The District will work very closely with developers, community planners and other water distributors to implement water conservation i.e. appropriate rate structure, suitable distribution system and delivery options should this become a prevalent concern.

To provide a local economical agricultural community, agricultural food and fiber, plus other amenities that an irrigated agricultural community provides, water usage in the MFID area is expected to remain nearly the same.

Very long range water use needs for existing crops may increase if global warming occurs. Local research could provide crop varieties that will provide similar yields, have acceptable quality and economic benefit, and with nearly the same water requirements.

Should changes in cropping pattern, smaller acreages of specialty crops, or urbanization accelerate, adjustments will probably have to be made in MFID operational procedures and policies. The district is not aware of any governmental long term planning activities that affect the supply of irrigation water to agricultural lands in the upper Hood River Valley.

B. Conservation and Technology

It is anticipated that new computer based technology to improve delivery and on-farm water use efficiencies in an area (i.e. "Agrimet", etc.) will probably not be used to any great extent in the near future. The MFID distribution system capacity is limited, having been installed over many years to deliver traditional volumes of water to 6365 acres irrigated. Typically less than full irrigation is practiced, even though MFID is an “on demand” system. Only in April, May and perhaps June, when significant winter carry over soil moisture is present, is the MFID delivery system capacity able to provide sufficient water for the full (calculated) crop irrigation requirement. Therefore, precise plant water need as determined by weather stations, historical data and computer calculations is not as appropriate in MFID as in irrigation Districts where water supplies can be adjusted. Typically deficit irrigation is practiced throughout the growing season. Weather stations, coupled with computer assisted calculations is the most effective method to estimate future crop water needs.

Agriculture agencies providing research, financial and technical assistance, i.e. ARS, NRCS, FSA, OSU, etc., will continue to promote the adoption of new water conservation practices.

C. Potential New Sources of Water (Regional, Local, etc.)

Developed water sources on the northern slopes of Mount Hood are the only water sources available to Middle Fork Irrigation District. It would be extremely difficult to obtain diversion permits from other watershed based streams (i.e. Crystal Spring Creek, Tilly Jane Creek, East Fork Hood River, etc.) located in the area. Construction and environmental costs would be high. The District is aware of a reserved amount of winter surface water in the East fork above Dog River. This water is reserved for "multi use" and could be appropriated for use as irrigation water supply. There is a county wide planning effort currently underway, the result of which should be available in coming years. If deemed feasible the district will pursue this source in order to offset current deficits.

Historically wells have not been a realistic irrigation water source in the Upper Hood River Valley. To date most wells are low volume wells. One or more high volume groundwater sources could minimize dependence upon glacial sources and leave more clean water in-stream. The district is investigating the construction of large volume wells to supply summer water demands.

X. Adopted Plan Elements

A. Schedule for Conservation Program Implementation

This Water Management / Conservation Plan will be implemented upon agreement by: the Middle Fork Irrigation District Board of Directors and the Oregon Water Resources Department.

B. Monitoring Implementation of Projects / Measures

Results of the implementation of any portion of this plan will be determined by net effects, i.e. total water conservation impact on the District's delivery opportunities, District cost per acre-foot of water conserved, marketing potential of water conserved, plus other effects as District staff sees necessary.

C. Schedule of Plan Update

Review of this Water Management / Conservation Plan, for updating needs, will be provided by Middle Fork Irrigation District at least every 5 years.

XI. Glossary/Definitions

Terminology and units relating to irrigation and the Water Management / Conservation Plan include the following. These definitions are obtained from published professional irrigation and related documents.

Application Efficiency (E_a): The ratio of the average depth of irrigation water applied, stored in the root zone and used by the crop to the average depth of irrigation water applied, expressed as a percentage.

Average Annual Precipitation: The long term or historic (generally 30 year or more) arithmetic mean of precipitation (rain, snow, sleet, hail, etc.) received by an area.

Average Daily Crop Use Rate (ET): Calculated or measured water used by plants in one day through evapotranspiration, expressed as acre-inches per acre per day, (or inches per day).

Border Irrigation: Surface irrigation by flooding strips of land, rectangular in shape, usually level perpendicular to the irrigation slope, surrounded by dikes. Water is applied at a rate sufficient to move it down the strip in a uniform sheet.

Carryover Soil Moisture: Moisture stored in the soil within the root zone during the winter, at times when the crop is dormant, or before the crop is planted. This moisture is available to help meet water needs of the next crop to be grown, expressed as acre-inches per acre, (or inches).

Cipolletti Weir: A sharp-crested trapezoidal weir with sides inclining outwardly at a slope of 1 horizontal to 4 vertical.

Control Structure: Water regulating structure, usually for open channel flow conditions.

Conveyance Efficiency: The ratio of the water delivered to the total water diverted or pumped into an open channel or pipeline at the upstream end, expressed as a percentage.

Conveyance Loss: Loss of water from a channel or pipe during transport, including losses due to seepage, leakage, evaporation, and transpiration by plants growing in or near the channel.

Crop Evapotranspiration (ET): The amount of water used by the crop in transpiration and building of plant tissue, and that evaporated from adjacent soil or intercepted by plant foliage. It is expressed as depth in inches or as volume in acre-inches per acre. It can be daily, weekly, monthly, or seasonal. Sometimes referred to as consumptive use (CU).

Crop Water Use or Needs: Calculated or measured water used or needed by plants, expressed in acre-inches per acre per unit time, i.e. day or month or year

Deep Percolation (DP): Water that moves downward through the soil profile below the plant root zone and is not available for plant use.

Deficit irrigation: An irrigation water management alternative wherein the soil in the plant root zone is not refilled to field capacity. Deficit irrigation may occur during a single irrigation or for a part of the growing season, in all or part of the field. It can be due to a management decision or lack of an adequate water supply.

Delivery, Delivery Box: Water control structure for diverting water from a canal to a farm unit, often including a measuring device. Also called, delivery site, delivery facility, turnout, etc.

Demand Irrigation Delivery: Irrigation water delivery procedure where each irrigator may request irrigation water in the amount needed and at the time desired.

Depth of Irrigation: Depth of water applied, measured in acre inches per acre (acre-inches/acre), or inches.

Design Efficiency, Potential Application Efficiency : Potential or design application efficiencies are usually those recommended in irrigation guides and in various tables and charts provided by various resource agencies, manufacturers, etc. These efficiencies are typically used for designing irrigation systems in establishing uniformity of coverage in a field or irrigation set. These efficiency recommendations usually assume good operation and management and maintenance of a well-designed and installed system. These efficiencies do not apply as seasonal water use efficiencies where less than adequate management and missuses creep in. They may apply, but only where the irrigator has a top notch irrigation system, operates it per design/plan, and is following an above average irrigation water management plan that incorporates irrigation scheduling techniques, i.e. soil moisture or plant water tension monitoring, following “Agrimet” scheduling data, deficit irrigating, etc

Distribution System: A network of open canals or pipelines to distribute irrigation water at a specific design rate to multiple outlets on a farm or in a community.

Distribution Uniformity (DU): A measure of the uniformity with which irrigation water is applied, i.e. $DU_{low\ quarter}$ (for a sprinkler set is): the ratio of the average low-quarter to the average depth applied.

Drip Irrigation: A micro irrigation application system (low pressure and low volume) wherein water is applied to the soil surface as drops or small streams through emitters.

Effective Precipitation (P_e): The portion of precipitation that is available to meet crop evapotranspiration. It does not include precipitation that is lost to runoff, deep percolation or evaporation before the crop can use it.

Evaporation: Conversion of liquid water to vapor, i.e. evaporation of water from a free surface.

Evapotranspiration (ET): The combination of water transpired from vegetation and evaporated from soil and plant surfaces. Sometimes called: Crop Evapotranspiration, Consumptive Use (CU)

Flood Irrigation, Wild Flooding: A surface irrigation system where water is applied to the soil surface without much control.

Flume:

1. Open conduit for conveying water across obstructions.
2. An entire canal or lateral elevated above natural ground, an aqueduct.
3. A specially calibrated structure for measuring open channel flows.

Furrow Irrigation: A surface irrigation system where water is supplied to small channels or furrows to guide water down slope and prevent cross flow. Called rill or corrugation irrigation in some areas.

Gate, Slide Gate, Head gate, etc.: A device used to control the flow of water to, from, or in a pipeline, or open channel. It may be opened and closed by screw or slide action either manually or by electric, hydraulic or pneumatic actuators. In open channels, gates slide on rails, and are used to control drainage or irrigation water.

Gated Pipe: Portable pipe with small gates installed at regular intervals along one side for distributing irrigation water to corrugations, furrows or borders.

Growing Season: The period, often the frost-free period, during which the climate is such that crops can be produced.

Head Gate: Water control structure at the entrance to a conduit or canal, or delivery point.

Infiltration: Process of water movement through the soil surface into the soil matrix.

Irrecoverable Water Loss: Water loss that becomes unavailable for irrigation reuse through evaporation, phreatophyte transpiration, or ground-water recharge that is not economically recoverable.

Irrigable Area: Area capable of being irrigated, principally based on availability of water, suitable soils, and topography of land.

Irrigation: Applying water to the land for growing crops, reclaiming soils, temperature modification, improving crop quality, etc.

Irrigation - District, Company, etc.: A cooperative, self-governing semipublic organization set up as a subdivision of a state or local government to deliver irrigation water.

Irrigation Efficiency (E_I): The ratio of the average depth of irrigation water beneficially used to the average depth applied, expressed as a percentage. Generally used to express overall seasonal irrigation efficiency.

Irrigation Method: One of four irrigation methods used to apply irrigation water: Surface, Sprinkle, Micro and Sub irrigation. One or more irrigation systems can be used to apply water by each irrigation method.

Irrigation Scheduling: Determining when to irrigate and how much water to apply, based upon measurements or estimates using soil moisture monitoring, and/or calculated crop evapotranspiration, i.e. “Agrimet” supplied data.

Irrigation System: Physical components (i.e. pumps, pipelines, valves, nozzles, ditches, gates, siphon tubes, turnout structures, etc.) and management techniques used to apply irrigation water by an irrigation method. All properly designed and managed irrigation systems have the potential to uniformly apply water across a field.

Irrigation Water Management (IWM): Managing water resources (precipitation, applied irrigation water, humidity, etc.) to optimize water use by the plant. Soil and plant resources and climatic factors must also be considered.

Irrigation Water Requirement (IR): The total irrigation requirement (IR) including net crop requirement (ET) less effective precipitation, plus any losses incurred in distribution and application. It is usually expressed as depth of water in acre-inches per acre, or inches. Losses include wind drift, evaporation, deep percolation, runoff, losses due to non-uniform application, etc. A seasonal gross IR may include unavoidable “over irrigation”, i.e. deep percolation at the head end of a surface irrigated field.

Land Leveling, Land Grading, Precision Land Leveling: Shaping the surface of the soil to planned elevations and grades.

Micro Irrigation: The frequent application of low volume, low pressure quantities of water as drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line. The micro irrigation method encompasses a number of application systems or concepts such as bubbler, drip, trickle, line source, mist, or spray.

Net Irrigation: The actual amount of applied irrigation water stored in the soil for plant use. Also includes water applied for crop quality and temperature modification, i.e. frost control, cooling plant foliage and fruit, etc.) and salt management. Application losses such as evaporation, runoff and deep percolation are not included. Net irrigation is usually measured in acre-inches per acre of water depth applied.

Operational Spills, Spills: Planned or emergency spills made along or at the end of an open canal or lateral in an irrigation water distribution system. Planned spills include the discharge of "administrative", “management” or "carry through water" carried in laterals, to allow turn outs to be opened and closed without precision management of lateral flow rates.

Emergency spill structures include overflow structures to discharge precipitation runoff waters that have entered an irrigation water delivery system, and relief gates to discharge irrigation water in case of ditch, structure or electrical power failure. Typically, planned and emergency spill structures discharge water into a natural water course or protected channel or into down slope irrigation District facilities.

Spill Leaving the District: Non-recoverable spill water leaving the District boundary.

Parshall Flume: An open-channel water flow measuring device which is a part of a group of short-throated flumes that control discharge by achieving critical flow with curving streamlines in a contracted throat section. Side-walls of the throat section are parallel but the floor slopes downward in the direction of flow then rises again in a diverging side wall section. Calibrations are based on laboratory ratings. When constructed with precision accuracy, the Parshall flume can be used for measuring water flow rates with very small total head loss. There are 10 critical edges and surfaces, which must be met for construction of an accurate Parshall flume. (Installation of long-throated flumes, i.e. ramp type flumes, are recommended for Parshall flume sites. Long-throated flumes have one critical surface, and it is level).

Peak Use Rate: The maximum rate which a crop uses water, measured in inches (acre-inches per acre) per unit time, i.e. inches per month, inches per week, inches per day, etc.

Peak Period ET or IR: The average daily or monthly evapotranspiration rate for a crop during the peak water use period or year.

Potential Application Efficiency, Design Efficiency: Potential or design application efficiencies are usually those recommended in irrigation guides and in various tables and charts provided by various resource agencies, manufacturers, etc. These efficiencies are typically used for designing irrigation systems in establishing uniformity of coverage in a field or irrigation set. These efficiency recommendations usually assume good operation and management and maintenance of a well-designed and installed system. These efficiencies do not apply as seasonal water use efficiencies where less than adequate management and missuses creep in. They may apply, but only where the irrigator has a top notch irrigation system, operates it per design/plan, and is following an above average irrigation water management plan that incorporates irrigation scheduling techniques, i.e. soil moisture or plant water tension monitoring, following “Agrimet” scheduling data, deficit irrigating, etc

Ramp Flume: Open-channel water flow measuring device that is part of a group of long throated flumes and broad crested weirs. The side-wall of the throat section are parallel but the floor slopes upward in the direction of flow, is flat, then drops suddenly as flow exits the measuring device, thereby achieving critical flow conditions. Sometimes called a Replogle flume or modified broadcrested weir.

Rectangular Weir: A sharp-crested weir with a horizontal weir edge and vertical sides.

Replogle Flume: See ramp flume

Return-flow Facilities, Reuse Facilities: A system of ditches, pipelines, pump(s) and reservoirs to collect and convey surface or subsurface runoff from an irrigated field for reuse. Sometimes called tail water reuse facilities or pump-back facilities.

Rotational Delivery System: A management technique used for community irrigation water delivery systems, in which water deliveries are rotated among water users; often at a frequency determined by water supply availability rather than crop water need. This method of managing water deliveries results in some of the lowest on farm irrigation water application efficiencies, except where continuous delivery results in very small deliveries.

Runoff (RO): Surface water leaving a field or farm, resulting from surface irrigation tail water, applying water with sprinklers at a rate greater than soil infiltration and surface storage, over irrigation and precipitation.

Seepage, Seepage Loss, Leakage, etc.: Water escaping below or out from water conveyance facilities such as pipelines, open ditches, canals, natural channels and water ways.

Sprinkle Irrigation: Method of irrigation in which water is sprayed or sprinkled through the air to plant or ground surfaces. See sprinkler irrigation system.

Sprinkler Irrigation System: Facility used to distribute water by the sprinkle irrigation method. Sprinkler systems are defined in the following general categories:

- Periodic-move system - A system of laterals, sprinkler heads (i.e. gun types) or booms, that are moved between irrigation settings. They remain stationary while applying water.
- Fixed/solid-set system - A system of portable surface or permanently buried laterals totally covering the irrigated area or field. Typically several adjacent laterals or heads are operated at one time. Portable laterals are typically removed from the field at end of germination, plant establishment or the irrigation season and replaced the next irrigation season.
- Continuous/self-move system - A lateral, sprinkler (i.e. traveler) or boom that is continuous or self moving while water is being applied. Power for moving the facility is typically provided by electric or hydraulic (water) motors or small diesel engines.

Specific types of sprinkler systems and general category include:

Boom: An elevated, cantilevered boom with sprinklers mounted on a central stand. The sprinkler-nozzle trajectory back pressure rotates the boom about a central pivot, which is towed across the field by a cable attached to a winch or tractor. Can be either periodic move or continuous move type system.

Center pivot: An automated irrigation system consisting of a sprinkler lateral rotating about a pivot point and supported by a number of self-propelled towers. Water is supplied at the pivot point and flows outward through the pipeline supplying the individual sprinklers or spray heads. A continuous/self move type system.

Corner pivot: An additional span or other equipment attached to the end of a center pivot irrigation system that allows the overall radius to increase or decrease in relation to field boundaries.

Gun type: A single sprinkler head with large diameter nozzles, supported on skids or wheels. Periodically moved by hand or mechanically with a tractor, cable or water supply hose. When the travel lane (or path) has been irrigated the sprinkler head is relocated at the far end of the next travel lane and irrigation continues.

Lateral move, linear move: An automated irrigation machine consisting of a sprinkler line supported by a number of self-propelled towers. The entire unit moves in a generally straight path perpendicular to the lateral and irrigates a basically rectangular area. A continuous/self move type system.

Portable hand move: Sprinkler system which is moved to the next irrigation set by uncoupling and picking up the pipes manually, requiring no special tools. A periodic move type system.

Side-move sprinkler: A sprinkler system with the supply pipe supported on carriages and towing small diameter trailing pipelines each fitted with several sprinkler heads. A periodic move type system.

Side-roll (wheel line) sprinkler: The supply pipe is usually mounted on wheels with the pipe as the axle and where the system is moved across the field by rotating the pipeline by engine power. A periodic move type system.

Solid-set, fixed-set, etc.: System which covers the complete field with pipes and sprinklers in such a manner that all of the field can be irrigated without moving any of the system. Laterals may be permanently buried or portable.

Towed sprinkler: System where lateral lines are mounted on wheels, sleds, or skids, and are pulled or towed in a direction approximately parallel to the lateral. Rollers or wheels are secured in the ground near the main water supply line to force an offset in the tow path equal to one half the distance the lateral would have been moved by hand. A periodic move type system.

Traveler: A single large "gun" type sprinkler head with a large diameter nozzle mounted on a unit which is continuously moved across the field by supply hose or cable. The hose reel may be mounted with the sprinkler head on a trailer or on a separate trailer secured at the water supply main line, which is typically located at or near the center of the field. Sometimes called traveling gun or hose-pull.

Surface Irrigation: Broad class of irrigation systems in which water is distributed over the soil surface by gravity flow (preferred term is surface irrigation method).

Tail water, runoff, (RO): Surface irrigation system water leaving a field or farm from the downstream end of a graded furrow, corrugation, border, etc. Best surface irrigation distribution uniformity across the field is obtained with 30 to 50% tail-water runoff, unless tail-water reuse facilities are used.

Tail water Recovery and Reuse: Collection and reuse facilities collect irrigation runoff and return it to the same, adjacent, or lower fields for irrigation use. If the water is applied to adjacent or lower lying fields, it is termed sequence use. One option is to reduce the incoming water supply by the amount equivalent to the return rate being added. Only the lowest elevation field will have tailwater runoff. Reuse of tail water will increase overall irrigation efficiency when it is used to meet down slope delivery needs.

Trapezoidal Weir: A sharp-crested weir of trapezoidal shape.

Trickle Irrigation: A micro irrigation application system (low pressure and low volume) wherein water is applied to the soil surface as drops or small streams through emitters. (Preferred term is Drip Irrigation.)

Turnout: (See Delivery box.)

Water Conveyance Efficiency: Ratio of the volume of irrigation water delivered by a distribution system to the water introduced into the system.

Water Rights: State administered legal rights to use water supplies derived from court decisions or statutory enactments.

Weirs: Any of a group of flow measuring devices for open-channel flow. Weirs can be either sharp-crested or broad-crested, however they are typically sharp crested. Flow opening may be rectangular, triangular, trapezoidal (Cipolletti) or specially shaped to make the discharge linear with flow depth.

Units typically used in irrigation:

1 acre-inch (ac-in)	= amount or volume of water 1 inch deep over 1 acre
1 acre-foot (ac-ft, AF)	= amount or volume of water 1 foot deep over 1 acre
1 acre-foot	= 43,560 cubic feet
1 cubic foot per second (cfs)	= rounded off to 450 gpm
	= rounded off to 1 ac-in per hour
	= rounded off to 2 ac-ft per 24 hour day
	= 40 miners inches (Oregon)
1 miners inch of water	= 11.20 gpm (Oregon)
1 million gallon	= 3.0689 acre-feet (ac-ft)
1 million gallons per day	= 695 gallons per minute (gpm)
	= 1.547 cubic feet per second (cfs)
1 cubic foot of water	= 7.48 gallons

1/ References: NRCS, National Engineering Handbook, Part 652, "Irrigation Guide", 1997; American Society of Civil Engineers, Journal of Irrigation and Drainage Engineering, November / December, 1997; American Society of Agricultural Engineers Standards, ASAE S526, Soil and Water Terminology, etc.

APPENDIX A

2002 - Average Water Use Year

2003 - High Water Use Year

2008 - Low Water Use Year

MIDDLE FORK IRRIGATION DISTRICT
Average Water Use Year
Irrigation Year – 2002

Facility Unit	Clear AF Flow	Evans AF Flow	Higgins AF Flow	Dykstra AF Flow	Rogers AF Flow	Sato AF Flow	Halliday AF Flow	Alexander AF Flow	Emil Creek AF Flow
Apr-02	1670	0	0	0	0	0	0	0	0
May-02	1773	0	0	0	0	0	0	0	0
Jun-02	2428	150	0	7	154	0	0	32	32
Jul-02	2373	133	0	19	233	0	0	34	34
Aug-02	1642	119	0	28	201	0	0	34	34
Sep-02	726	115	0	10	125	0	0	32	32
Oct-02	626	0	0	0	0	0	0	0	0

Facility Unit	Clear Br/Lake AF Storage	Emil Pond AF Storage	Coe AF Flow	Eliot AF Flow	Power AF Flow	Irrigation AF Flow 1/
Apr-02	2343	10.7	1200	138	2,463	545
May-02	3415	10.7	1253	230	2,148	1,108
Jun-02	3627	10.7	601	724	982	3,146
Jul-02	3577	10.7	232	1161	501	3,718
Aug-02	3147	10.7	783	1363	531	3,673
Sep-02	2713	10.7	1166	929	1,791	1,344
Oct-02	0	10.7	1019	381	1,671	355
Total					10,087	13,889

1/Water diverted for irrigation and temperature control purposes (without power)

MIDDLE FORK IRRIGATION DISTRICT
High Water Use Year
Irrigation Year – 2003

Facility Unit	Clear AF Flow	Evans AF Flow	Higgins AF Flow	Dykstra AF Flow	Rogers AF Flow	Sato AF Flow	Halliday AF Flow	Alexander AF Flow	Emil Creek AF Flow
Apr-03	1769	0	0	0	0	0	0	0	0
May-03	1450	0	0	0	0	0	0	0	0
Jun-03	1877	122	0	71	106	0	0	0	0
Jul-03	2159	111	0	37	110	0	0	0	65
Aug-03	1740	96	0	39	110	0	0	0	67
Sep-03	942	97	0	12	106	0	0	0	67
Oct-03	296	61	0	0	0	0	0	0	0

Facility Unit	Clear Br/Lake AF Storage	Emil Pond AF Storage	Coe AF Flow	Eliot AF Flow	Power AF Flow	Irrigation AF Flow 1/
Apr-03	3655	10.7	1256	140	2,557	608
May-03	3126	10.7	1251	325	2,386	640
Jun-03	3427	10.7	934	938	850	3,263
Jul-03	3415	10.7	464	1206	363	3,791
Aug-03	2391	10.7	479	1452	320	3,663
Sep-03	1794	10.7	673	757	735	1,917
Oct-03	1433	10.7	470	368	815	380
Total					8,026	14,262

1/Water diverted for irrigation and temperature control purposes (without power)

MIDDLE FORK IRRIGATION DISTRICT
Average Water Use Year
Irrigation Year – 2008

Facility Unit	Clear AF Flow	Evans AF Flow	Higgins AF Flow	Dykstra AF Flow	Rogers AF Flow	Sato AF Flow	Halliday AF Flow	Alexander AF Flow	Emil Creek AF Flow
Apr-0	1848	60	0	0	0	0	0	0	0
May-0	1812	60	0	0	0	0	0	0	0
Jun-0	2111	100	1	119	92	92	1	1	32
Jul-0	2171	121	0	122	95	95	0	0	34
Aug-0	2090	120	0	122	95	95	0	0	34
Sep-0	1562	90	0	119	92	92	0	0	32
Oct-0	1256	60	0	0	0	0	0	0	

Facility Unit	Clear Br/Lake AF Storage	Emil Pond AF Storage	Coe AF Flow	Eliot AF Flow	Power AF Flow	Irrigation AF Flow 1/
Apr-02	2999	10.7	829	0	2596	141
May-02	2670	10.7	737	0	2582	27
Jun-02	3640	10.7	600	228	1036	2250
Jul-02	3627	10.7	532	574	242	3407
Aug-02	3565	10.7	291	564	502	2814
Sep-02	3377	10.7	741	452	1236	1911
Oct-02	3094	10.7	1019	62	2256	0
Total					10450	10550

1/Water diverted for irrigation and temperature control purposes (without power)

APPENDIX B

PERSPECTIVES ON DEFICIT IRRIGATION

By

Marshall English

And

Syed Navaid Raja

Perspectives on Deficit Irrigation

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Abstract

An analysis of deficit irrigation in three quite different situations was conducted to develop perspectives on the potential benefits and risks associated with this irrigation strategy. Existing crop yield functions and cost functions, developed independently of the present research, were used to estimate the levels of applied water that would produce maximum net income in each situation. These same functions were also used to estimate the degree to which the three crops could be under-irrigated without reducing income below that which would be earned under full irrigation. The analysis encompassed wheat production in the northwestern United States, cotton production in California and maize production in Zimbabwe. Results suggest that (1) deficits of between 15 and 59 percent would be economically optimal, depending on the circumstances, and (2) the estimated margin for error in these estimates is quite wide.

Introduction

Deficit irrigation, the deliberate and systematic under-irrigation of crops, is a common practice in many areas of the world (e.g. English, et al, 1990; Trimmer, 1990; Tyagi, 1987; Jurriens and Wester, 1994). Governmental agencies in water-short countries such as India and the Republic of South Africa have implicitly endorsed the concept of deficit irrigation by recommending that irrigation planning be based on a "50% dependable" supply of water (Chitale, 1987). However in the academic world deficit irrigation it is not usually treated as a practical alternative to full irrigation. A review of recent text books dealing with irrigation system design found that formal design procedures were always predicted on full irrigation. Some texts explicitly stipulated that the system should deliver enough water to meet full crop water demands (c.f. ASCE, 1990, p 268; Walker and Skogerboe, 1987, p25). In other texts the design procedure was based on a maximum allowable soil water depletion. The maximum depletion level would be chosen by the designer, but the depletion levels recommended in the design texts all implied full irrigation (c.f.;Keller and Bleisner, 1990, p 32; James, 1988, p 6). Only one of the texts reviewed for this paper even mentions the concept of partial irrigation (Cuenca, 1989). Cuenca suggests that under some circumstances the designer might allow for greater soil water depletion, which could result in reduced yields as an economic tradeoff against the higher costs of more intensive irrigation. However, Cuenca then cautions the reader that this approach entails a risk of "serious yield reduction due to unexpected equipment failure or extremely dry meteorological conditions."

The apparent reluctance to fully explore the concept of deficit irrigation in the formal context of text books may be due to a concern that the potential benefits of this technique may not justify the associated risk. The goal of this paper is to develop a clearer perspective on this issue. This paper utilizes past research to assess the benefits and risks of deficit irrigation in a variety of real-world situations involving different crops, soils, weather and economic circumstances.

The concept of deficit irrigation

A number of researchers have analyzed the economics of deficit irrigation in specific circumstances and have concluded that this technique can increase net farm income (e.g., Stewart, et. Al., 1974; Gulati and Murty, 1979; Dudley, et. Al., 1971; Howell, et al., 1975; Martin el at., 1989; Kumar and Kephar, 1980; English, 1990). The potential benefits of deficit irrigation derive from three factors: increased irrigation efficiency, reduced costs of irrigation and the opportunity costs of water (English, et al., 1990). Figures 1(a) and 1 (b) illustrate the concept. The discrete data shown in Figure 1 (a) are yields of winter wheat per unit of irrigated land. These data, which are from field experiments in eastern Oregon (English and Nakamura, 1989) were used to derive a quadratic production function, y(w), which relates applied water to crop yields. (This functional relationship will be used later in the analysis of Case 1).

Estimated revenue from irrigation of this field can be represented by a revenue function relating gross income to applied water. The revenue function would be the product of the production function and the crop price, defined by the equation:

Where *R(w)* is revenue per ha,*y(w)*is the crop production function, *w* is the depth of water applied and *Pç*

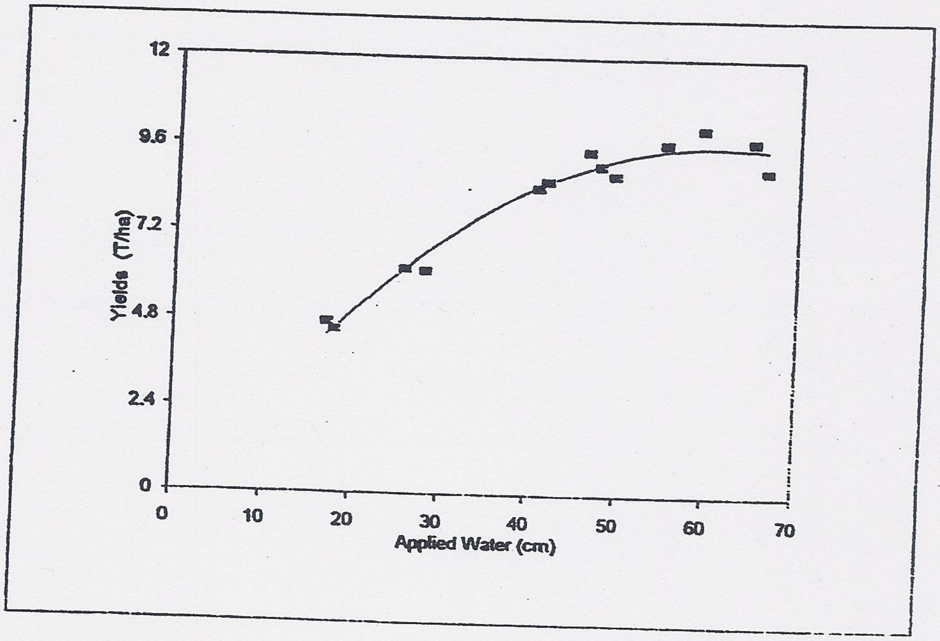

Figure 1a

Yield vs Applied Water: Case 1
Winter Wheat in Oregon

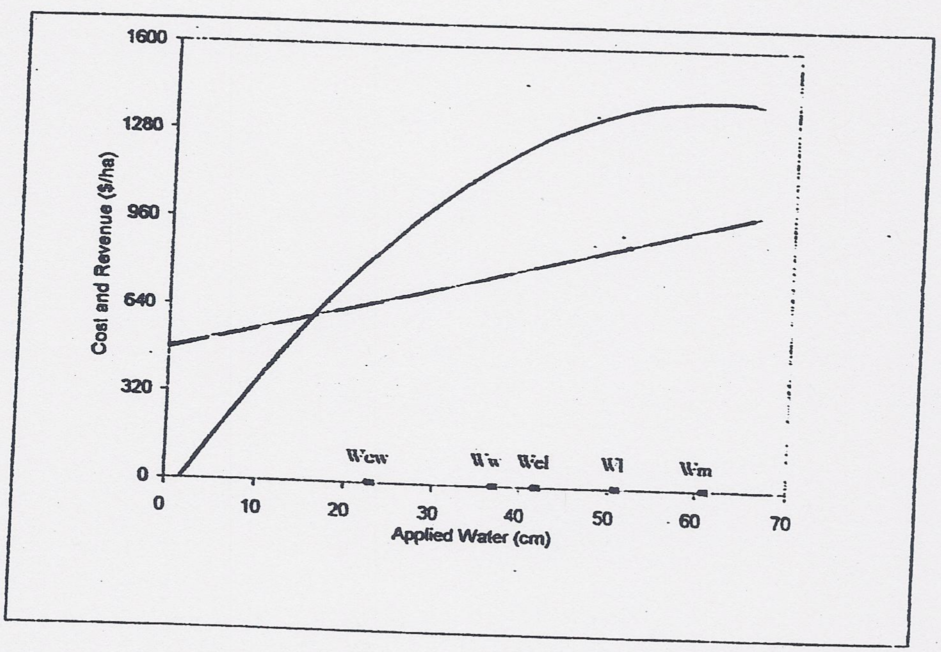

Figure 1b

Cost and Revenue Functions: Case 1
Winter Wheat in Oregon

$$R(w) = P_C \; y(w) \qquad (1)$$

where $R(w)$ is revenue per ha, $y(w)$ is the crop production function, w is the depth of water applied and P_c is the price per unit weight paid for the crop. The revenue function is shown as the curved line in Figure 1(b). The straight line in Figure 1(b) is a simple cost function, with an intercept that represents fixed costs and a slope that represents operating costs.[1] Profit, which is calculated by subtracting costs from revenues, is indicated by the vertical difference between these two lines.

W_m is the yield maximizing level of applied water. At that point the marginal water use efficiency is zero, since the application of additional water will produce no additional yield. On the other hand, if the amount of water applied is something less than W_m the marginal efficiency of the last increment of water will be greater than zero since an increment of water will produce some increment of yield, and the marginal efficiency will become progressively greater as water use is further reduced. This illustrates the first factors, the increasing efficiency associated with deficit irrigation.

Profit per unit of land will be maximized when the level of applied water reaches W_l, at which point the slope of the cost line equals the slope of the revenue line. At levels higher than W_l the cost line is steeper than the revenue line, so total costs are increasing faster than revenues. It is in the range between W_l and W_m that the farmer can benefit from reduced costs (the second factor). Additionally, a decision to use less water may enable the farmer to reduce capital and other fixed costs.

It is difficult to illustrate the third factor, the opportunity cost of water, with Figure 1(b), but a heuristic argument may suffice. Because efficiency and profit are both increased with reduced levels of applied water the net income per unit of applied water is increased. If the water saved by reducing the depth of irrigation is then used to bring additional land under irrigation with the same increased profit per unit of land, the total farm profit is increased still more. The net income from the additional land represents the opportunity cost of water. If additional land can be irrigated, the profit maximizing water use strategy would be to irrigate at a level below W_l, indicated by W_w in Figure 1(b).

Two other important points are shown in Figure 1(b). If applied water is reduced enough, a point will be reached at which the vertical difference between the cost and revenue lines is again equal to the difference at W_m. That point is illustrated by W_{el} for the land-limiting case and W_{ew} for the water limiting case. The range of applied water between either of those points and W_m might be referred to as

[1] The reader should note that some of the earlier analyses cited above accounted only for the direct costs of irrigation and did not account for other production costs. Such incomplete cost analyses lead to underestimation of the magnitude of deficit that would be optimal and the potential gain in net income that would be realized. It is important to keep in mind that reductions in applied water, and the accompanying reductions in yields, will usually imply reductions not only in the costs of irrigation but also in the costs of seed, fertilizers, harvest and other factors of production, and may also imply reduced capital costs for water delivery and application systems. English and Nuss (1982) analyzed potential savings that could be achieved by designing a system specifically for partial irrigation of a field of winter wheat in Oregon. The savings were partitioned into three categories; (1) reduced irrigation costs (energy, labor and maintenance), which accounted for 37% of savings; (2) reduced fixed costs (primarily capital costs), which accounted for 36% of savings; and (3) reductions in other production costs (cultural operations, chemical application, harvest and other costs) which accounted for 27% of savings.

the range of profitable deficits, since the net income associated with any deficit within that range will result in greater net income than would be realized with full irrigation.

There are circumstances where deficit irrigation is not appropriate. For example, in the case of potatoes in the Northwestern US soil moisture deficits that have little effect on yield may cause significant changes in tuber shape, an important determinant of quality (Robbins and Domingo ,1956; Sparks, 1958). Larsen and McMaster (1965) found that early season moisture stress which caused a 15 percent reduction in total yield of Russet Burbank potatoes resulted in a 27 percent decline in the highest valued component of yield. Conversely, water stress may enhance quality in other crops. For example deficits may improve the protein percentage of wheat and other grains, increase the fiber length and strength of cotton, and increase the sugar percentages in grapes, sugar beets and other crops. (Krieg, 1986; Musick and Porter, 1989).

Optimal levels of water use

The foregoing discussion outlines four levels of applied water that could be defined as optimal in one sense or another, and which might therefore be interesting to an analyst. They are:

a) the level of applied water at which crop yields per unit of land are maximized;
b) the level at which net income per unit of land is maximized;
c) the level at which net income per unit of water is maximized; and
d) the level at which yields per unit of water are maximized.

The optimum level of applied water for a particular situation will be that which produces the maximum profit or crop yield, per unit of land or per unit of water, depending on whether the goal is to maximize profits or food production and whether the most limiting resource is water or land. Additionally, as discussed above, there are two other levels of applied water which, though not optimal, should be of interest. They are the deficit levels at which net returns will be equal to those which would be realized by full irrigation.

English (1990) has derived equations for each of the application levels described above. The first equations presented in the original paper are completely general. The specific forms of those equations depend upon the forms of the cost and production functions that are utilized. For the particular case of a quadratic production function of the form

$$y(w) = a_1 + b_1 w + c_1 w^2 \qquad (2)$$

and a linear cost function of the form

$$c(w) = a_2 + b_2 w \qquad (3)$$

the following specific equations were also derived:

a) for the yield maximizing level of water use, W_m:

$$W_m = -\frac{b_1}{2c_1} \qquad (4)$$

b) for the profit maximizing level when land is the limiting resource, W_l:

$$W_l = \frac{b_2 - P_c b_1}{2P_c c_1} \qquad (5)$$

c) for the profit maximizing level when water is the limiting resource, W_w:

$$W_w = \left(\frac{P_c a_1 - a_2}{P_c c_1}\right)^{1/2} \qquad (6)$$

d) for the level of deficit irrigation at which net income will equal that at full irrigation when land is limiting, W_{el}:

$$W_{el} = \frac{b_2 - P_c b_1 + Z_1}{2P_c c_1} \qquad (7)$$

where

$$Z_1 = \left[(P_c b_1 - b_2)^2 - 4P_c c_1\left(\frac{P_c b_1^2}{4c_1} - \frac{b_1 b_2}{2c_1}\right)\right]^{1/2}$$

e) for the level of deficit irrigation at which net income will equal that at full irrigation when water is limiting, W_{ew}:

$$W_{ew} = \frac{-Z_2 + \left[Z_2^2 - 4P_c c_1(P_c a_1 - a_2)\right]^{1/2}}{2P_c c_1} \qquad (8)$$

where

$$Z_2 = \frac{P_c b_1^2 - 4a_2 c_1 + 4P_c a_1 c_1}{2b_1} \qquad (9)$$

The reader is referred to the original paper by English (1990) for the derivation of both the general and the specific equations presented above.

The risk associated with deficit irrigation

There is uncertainty associated with the above estimates of optimal water use. The production function, $y(w)$, cannot be known *a priori*, since yields will be affected by a number of unpredictable factors, including such things as climate, irrigation system failures, germination rates and the incidence of disease. Consequently, the production function used in the above equations will only be an estimate of the true relationship. The cost function and crop price may be relatively more predictable, but will be uncertain nevertheless. Use of these uncertain functions in the foregoing equations implies that the resulting estimates of optimum water use will also be uncertain, and these uncertainties imply risk.

The fact that there is risk does not preclude using deficit irrigation. English (1981) has shown that farmers will adjust their water use to reduce risk, but will accept some degree of risk in exchange for potential economic gains. Nevertheless, the concern for risk implies that crop yield models should be used not only to predict yields but also to quantify the uncertainty of yield predictions. While we cannot know the true yield functions *a priori*, we can use our estimates of these functions to develop some sense of the associated risk. Let us focus on W_m, the yield maximizing level of water use, and W_{el} or W_{ew}, the levels of deficit irrigation at which net income is just equal to that at full irrigation. In the range of water use between these levels, net income will be at least as great as it would be at full irrigation. The probability of being outside that range, with reduced income as a consequence, is a risk that a farmer takes by adopting a deficit irrigation strategy. The extent of this range of profitable deficits is therefore a qualitative indication of potential risk. If the profitable deficit range is narrow there is little margin for error in estimation of optimum water use. If the range is wide there is greater margin for error. One goal of this paper is to develop some perspective on this range of profitable deficits.

Case Studies

Case studies are presented below to illustrate the potential economic benefits of deficit irrigation and the range of profitable deficits in three different circumstances. The first case concerns wheat farming in the Northwestern US; the second is concerned with cotton farming in California; the third involves subsistence maize farming in southern Africa.

These analyses required appropriate cost and production functions. For the first two cases, quadratic production functions were derived directly from local field experiments, which made it possible to use equations 4 through 9 to determine the optima. The production function for the third case was a fourth degree polynomial taken from the literature (Solomon, 1985), so a numerical search procedure was used to derive the optima.

Linear cost functions were derived from estimates of typical production costs for each case. Because these cost estimates were drawn from a variety of sources, they are presented in a variety of formats. In each case the estimates were used to calculate total production costs, first with irrigation at a specified level, and then with no irrigation. The resulting two calculations were used to derive linear cost functions.

Case 1: Wheat farming in the Columbia Basin.

The first case study involved irrigation of winter wheat on a large, family operated farm in the Columbia Basin, an arid region in eastern Oregon. It is an area with limited water and abundant land,

and the farm in question has an opportunity to irrigate additional land if water becomes available. This is, therefore, a water limiting case.

The wheat production function used in this case was derived from local field experiments (English and Nakamura, 1989) in which alternative strategies for deficit irrigation of a common, local variety of winter wheat were tested: (1) by irrigating at intervals ranging from two days to four weeks, and (2) by irrigating with different levels of applied water at two day and seven day intervals. The results of that earlier study were used in Figure 1(a). The following quadratic production function was derived from these data by linear regression:

$$y(w) = -0.5348 + 0.3326\,w - 0.00273w^2 \qquad (10)$$

In this case, *w* is expressed as cm, and y as kg/ha.

A cost function was derived from an earlier analysis of irrigation on this same farm (English and Nuss, 1982). Cost figures presented in that earlier analysis are summarized in Table 1, and from those figures the following linear cost function was derived:

$$c(w) = 482.30 + 7.79\,w \text{ \$/ha} \qquad (11)$$

Crop price was assumed to be $147.00 /T. Costs and revenues are expressed as U.S. dollars.

The relevant levels of applied water, derived using Equations 4 through 9, are summarized in Table 2. Though water is the limiting resource in this case, an analysis of both water-limiting and land-limiting situations was carried out. For the water limiting case, maximum net farm income would be realized by reducing applications from W_m to W_w. The resulting application would be 37 cm, a 39% deficit. At that point, net return per unit of water would be increased from 0.0745 $\$/m^3$ to 0.1110 $\$/m^3$, a gain of 49%. The lower limit of the range of profitable deficits for this case would be a deficit of 62%. Note that values of W_l and W_{el} which would apply to a land limiting case are also shown in Table 2 for added perspective.

Case 2: Cotton production in California

The second case concerns a corporate farm in the San Joaquin Valley, the arid central valley of California. Water supplies are limited, but there is no opportunity to expand irrigated acreage even if more water were available. This is therefore a land limiting case.

The following quadratic production function was derived by Cuenca, (1989) using experimental data collected at a nearby research station of the University of California:

$$y(w) = -781.1 + 29.85w - 0.091w^2 \qquad (12)$$

The units of applied water and yield are cm and kg/ha, respectively.

A cost function was derived from cost estimates (Table1) provided by Northwest Economic Associates (NEA, 1989), a consulting firm which had conducted an earlier analysis of water use on the farm in question. The NEA figures were presented in three broad categories; (1) fixed costs, which are independent of the level of production; (2) partially variable costs, which depend to some extent on production levels; and (3) costs of water. For purposes of this analysis, the partially variable costs were arbitrarily partitioned equally between fixed costs and variable costs. The resulting cost function was:

$$c(w) = 770 + 7.30w \quad \$/\text{ha} \qquad (13)$$

The crop price used for this case was or $1.59/kg.

Results of this second analysis are presented in Table 2. Maximum yield would occur at 164 cm of applied water. The economic optimum level of applied water for the land limiting case (W_l) would be 139 cm, a deficit of 15%. The deficit level at which income would equal that at full irrigation (W_{el}) would be 114 cm, a 30% deficit.

Case 3: Subsistence maize farming in Zimbabwe

The third case involves an irrigation scheme on communal lands near Mutoko, Zimbabwe. This is an area of small-holding, subsistence farming. The farm in question has one hectare of irrigated land and some additional land which could be irrigated if water were available, so this is a water limiting situation.

No local field data were available from which to derive production functions directly, so the following generic production function for maize was taken from the literature (Solomon, 1985):

$$y(w) = 6.0\left(-0.84 + 4.43\,W_R - 3.52\,W_R^2 + 1.11\,W_R^3 - 0.18\,W_R^4\right) \quad \text{T/ha} \qquad (14)$$

where: $$W_R = \frac{w + Rain}{W_{max}}$$

The rainfall used in the analysis was 156 mm, an amount that would just begin to produce a harvestable yield. W_{max}, the total available water (irrigation plus rainfall) was estimated to be 685 mm. The coefficient 6.0 represents an estimate of maximum attainable yield.

The costs of production for this third case were derived from various local sources, as discussed by English and Stoutjesdyke (1992). The resulting costs, shown in Table 1, are consensus figures for dry land and fully irrigated maize production. These two estimates were used to develop the following linear relationship between production costs and applied water:

$$c(w) = 730 + 1.58\,w \qquad \$/\text{ha-mm}$$

Table 1

Production Costs

Cost Categories	Costs ($/ha)
Case 1: Winter Wheat, Oregon	
Fixed costs (annualized)	
Field machinery	116.23
Field operations (tillage, planting, etc.)	114.73
Irrigation Equipment	152.36
Variable costs: Without Irrigation (1950 kg/ha)	
Nitrogen: 22.5 kg/ha	28.70
Seed	6.92
Harvest	63.36
Variable costs: Irrigated (8138 kg/ha)	
Irrigation @ 42.2 cm	137.59
Nitrogen: 117.9 kg/ha	150.44
Seed	29.65
Harvest	109.76
Total Costs:	
Unirrigated	482.30
Irrigated (42.2 cm)	810.76
Cost Function: 482.30 + 7.79 *w*	
Case 2: Cotton, California	
Fixed costs: includes land preparation, etc.	529.42
Partially variable costs (assumed 50% of the following costs are variable):	
Fertilizers	86.48
Defoliation materials	42.00
Harvest	254.51
Post harvest shredding	24.71
Irrigation operations (100 cm)	74.13
Cost of water (100 cm)	489.34
Total fixed costs	770.34
Total variable costs (100 cm water applied)	730.26
Cost Function: 770 + 7.30 *w*	
Case 3: Maize, Zimbabwe	
Variable Costs: Unirrigated (2.8 T/ha)	
Field preparation, planting	55.00
Fertilizer	245.00
Insecticide	2.00
Labor	330.00
Transport	52.00
Subtotal	684.00
Capital @ 13% (except labor)	46.00
Total	730.00
Variable Costs: Irrigated (5.8 T/ha)	
Field preparation, planting	165.00
Fertilizer	610.00
Insecticide	120.00
Labor	500.00
Transport	120.00
Irrigation (600 mm)	30.00
Subtotal	1545.00
Capital @ 13%	135.00
Total	1680.00
Cost Function: 730 + 1.58 *w*	

Table 2
Analysis of Alternative Levels
of Applied Water

	Water Use		Net Returns		Profit Increase at Optimum	
	Applied (cm)	Deficit (%)	To Land ($/ha)	To Water ($/m³)	Land Limiting (%)	Water Limiting (%)
<u>Case 1</u>: Wheat/Oregon						
W_m	61	—	453.70			
W_l	51	16%	491.51	0.0964	8.3%	
W_w	37	39%	414.81	0.1110		49.0%
W_{el}	42	31%	453.70	0.1080		
W_{ew}	23	62%	170.90	0.0745		
Case 2: Cotton/California						
W_m	164	—	682.87	.0416		
W_l	139	15%	774.96	.0558	13.2%	
W_w	118	28%	711.97	.0603		44.1%
W_{el}	114	30%	682.87	.0599		
W_{ew}	85	48%	353.00	.0415		
<u>Case 3</u>: Maize/Zimbabwe						
W_m	52.5	—	1651	0.315		
W_l	44.5	15%	1713	0.385	3.8%	
W_w	21.5	59%	1137	0.529		68%
W_{el}	36.6	30%	1651	0.450		
W_{ew}	9.8	81%	329	0.315		

Labor costs shown in Table 1 are based on the potential earnings of a laborer who leaves the farm to find other work. But there is some question about whether labor costs should be included in the analysis, since farm labor is often provided by family members who have no such outside labor opportunities. However, in the course of this analysis, it was found that labor costs did not appreciably influence the optimal levels of applied water for Case 3.

The units for applied water and yield in this case were mm and tons/ha respectively. The cost and revenue functions for case 3 are illustrated in Figure 2. Costs and income are expressed as Zimbwabe dollars. Maximum net income would be ZIM$ 1713.[2]

Optimal levels of applied water and the associated yields and net incomes were determined by a simple search procedure. The results of the analysis are summarized in Table 2. The optimum level of applied water would be 21.5 cm, a deficit of 59%. The equivalent deficit level, W_{ew}, would be 9.8 cm of water, an 81% deficit.

It is interesting to also consider total food production, which is a primary concern in the communal lands of Zimbabwe. As water use is reduced additional land can be brought into production, with a consequent increase in total food production. The results, shown in Table 3, suggest that total food production could be nearly doubled without reducing net farm income by irrigating at the W_{el} level.

Table 3.
Alternative Levels of Applied Water: Subsistence Maize Production in Zimbabwe.

	Water use (cm)	Yield (T/ha)	Irrigated Land (ha)	Total yield (T)
W_m	52.5	6.0	1.0	6.0
W_w	21.5 (59% deficit.)	4.13 (31% deficit)	2.44	10.1 (68% increase)
W_{el}	9.8 (81% deficit.)	2.23 (63% deficit)	5.36	11.9 (99% increase)

Discussion

Three analyses of deficit irrigation in real world situations were presented. The crop production functions and cost functions, which are critical to the analyses, were derived from independent work of other individuals as well as earlier research by the present authors. These relationships were used to explore the potential benefits and the margin for error in deficit irrigation.

In land-limiting situations the estimated optimal deficits were 15% or 16%, which represents appreciable water savings. The resulting gains in profit would range from 8% to 13%. Optimal deficits were much larger in the water-limiting cases, ranging from 28% to 59%, with associated gains in total

[2] The exchange rate in 1992 was approximately 5 Zimbabwe dollars for 1 U.S. dollar. The maximum net income from this one hectare farm would therefore be equivelant to US$ 343.

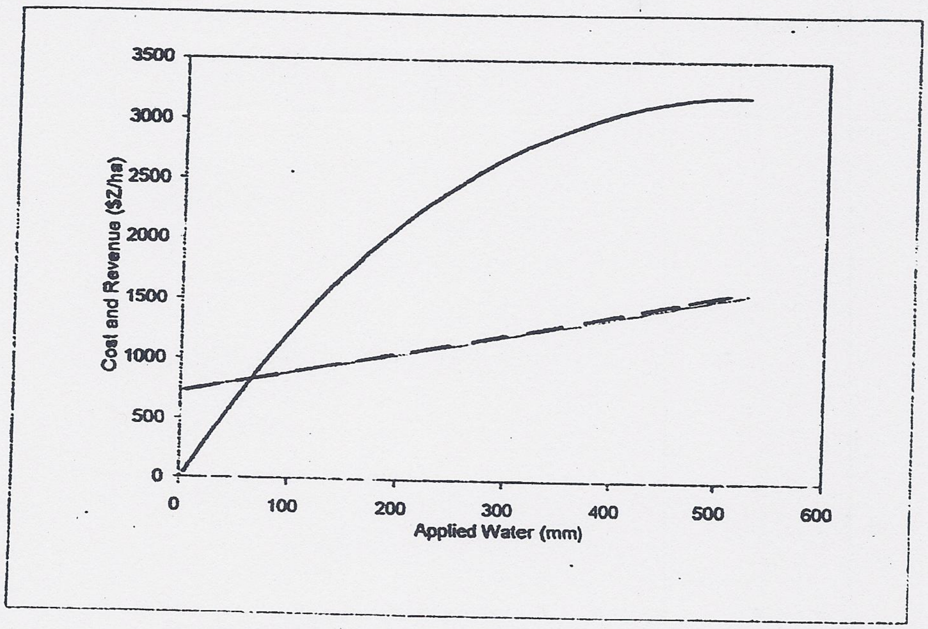

Figure 2

Cost and Revenue Functions: Case 3
Small Scale Maize Farming in Zimbabwe

farm income between 44% and 68%. The magnitude of these optimal deficits is consistent with earlier research by Martin, et al. (1989), English (1990) and others.

The potential benefits of deficit irrigation appear to be significant in these three cases. A central concern of this paper, however, is the risk the farmer takes in adopting such a strategy. This was addressed in a limited way by studying the range of irrigation deficits which would have been at least as profitable as full irrigation. That range was found to be quite wide. Deficits averaging 64% were found to be economically equivalent to full irrigation in the water limiting cases, and deficits averaging 30% were found to be equivalent to full irrigation in the land limiting cases. These results suggest that the margin of error in determination of optimum water use may be rather wide.

It should be noted that we have only considered one aspect of the issue of risk, the range of profitable deficits, which represents in a general way the margin for error. The magnitudes of possible errors in estimates of optimum applications have not been analyzed in this paper though other researchers have addressed some aspects of this question. For example, Martin, et al. (1989) evaluated the variability of W_m for three crops in Nebraska and found variations on the order of $\pm$25% in W_m from one season to another.

Conclusions

Existing production functions and cost functions were used to examine the potential economic benefits of deficit irrigation for three very different sets of circumstances. In situations where irrigable land is abundant and water is scarce the optimum strategy would be to underirrigate by 28 to 59 percent in the three cases studied. Even where water supplies are not limited the optimum strategy would entail deficits on the order of 15 percent.

Since the relationship between water use and crop yield is intrinsically uncertain, the analysis was extended to develop perspectives on the margin for error in determination of optimum levels of water use. Using the same production and cost functions it was found that net incomes would not be reduced by deficit irrigation unless the deficits are substantial, on the order of 30% when water is not limited and as much as 48% to 81% for the water limiting cases considered.

The conclusions presented here should not be regarded as either universal or absolute. Any analysis that employs the cost and production functions presented in this paper will arrive at essentially the same results, but alternative functions might reasonably have been used and would have produced different numbers. Likewise, the circumstances of these three case studies cannot be regarded as representative of all irrigated agriculture. Finally, the analyses were based on model estimates, and though the models were derived from field research they are still intrinsically uncertain. Such uncertainty is, in fact, a basic tenet of this paper Nevertheless, the results of these analyses are compelling enough to warrant serious attention. The potential advantages of deficit irrigation appear to be quite significant, particularly in a water-limiting situation, and the associated risks may be quite acceptable.

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APPENDIX C

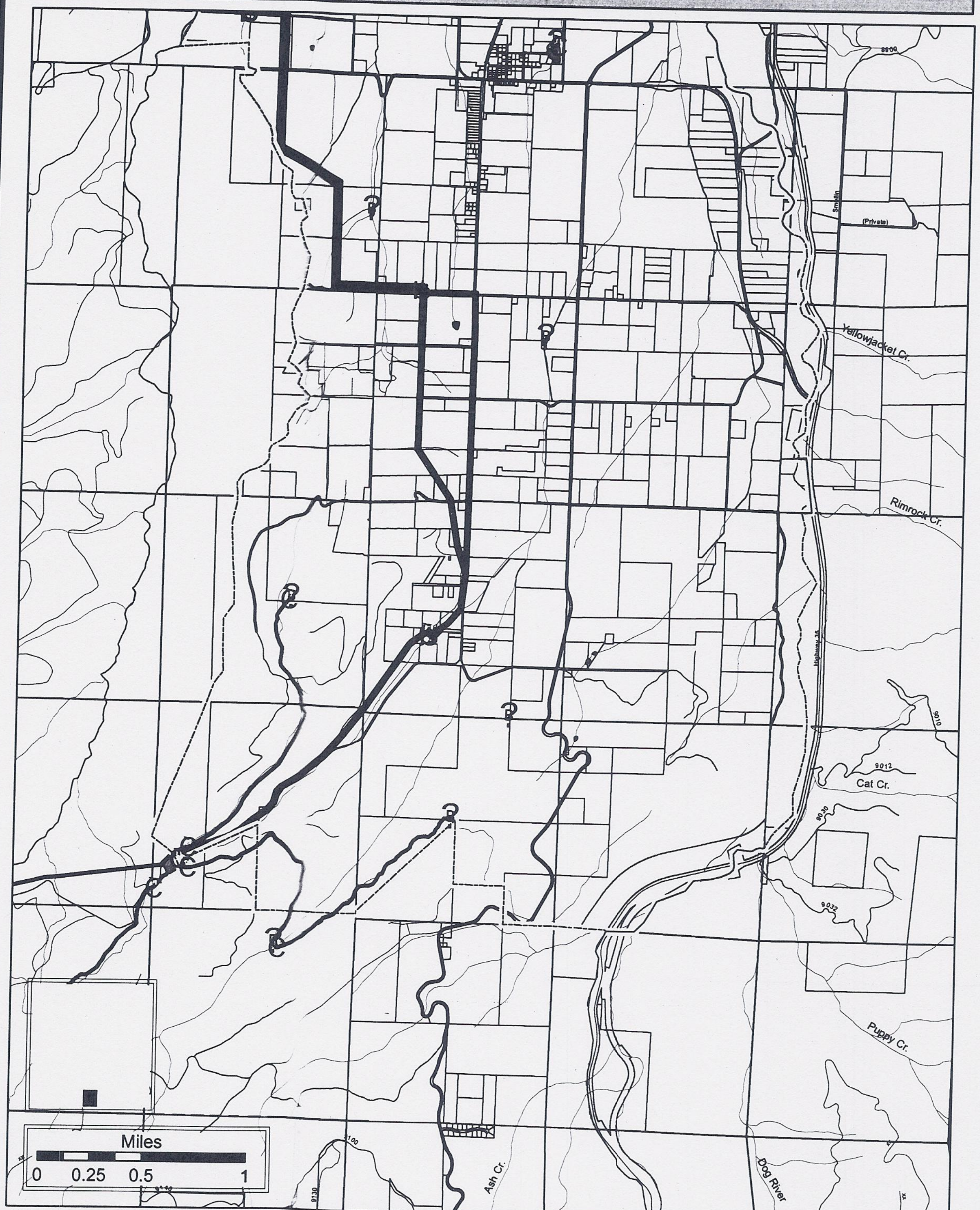
MIDDLE FORK IRRIGATION DISTRICT MAPS

8½" X 11" SYSTEM MAP (3 SHEETS)

11" X 17" GENERAL SOILS MAP (1 SHEET)

11" X 17" TOPOGRAPHIC MAP (2 SHEETS)

MIDDLE FORK IRRIGATION DISTRCT



Legend

- Power House
- Meter
- Intake
- MFID boundary
- Mainline
- West Evans Pipeline
- Open Ditch

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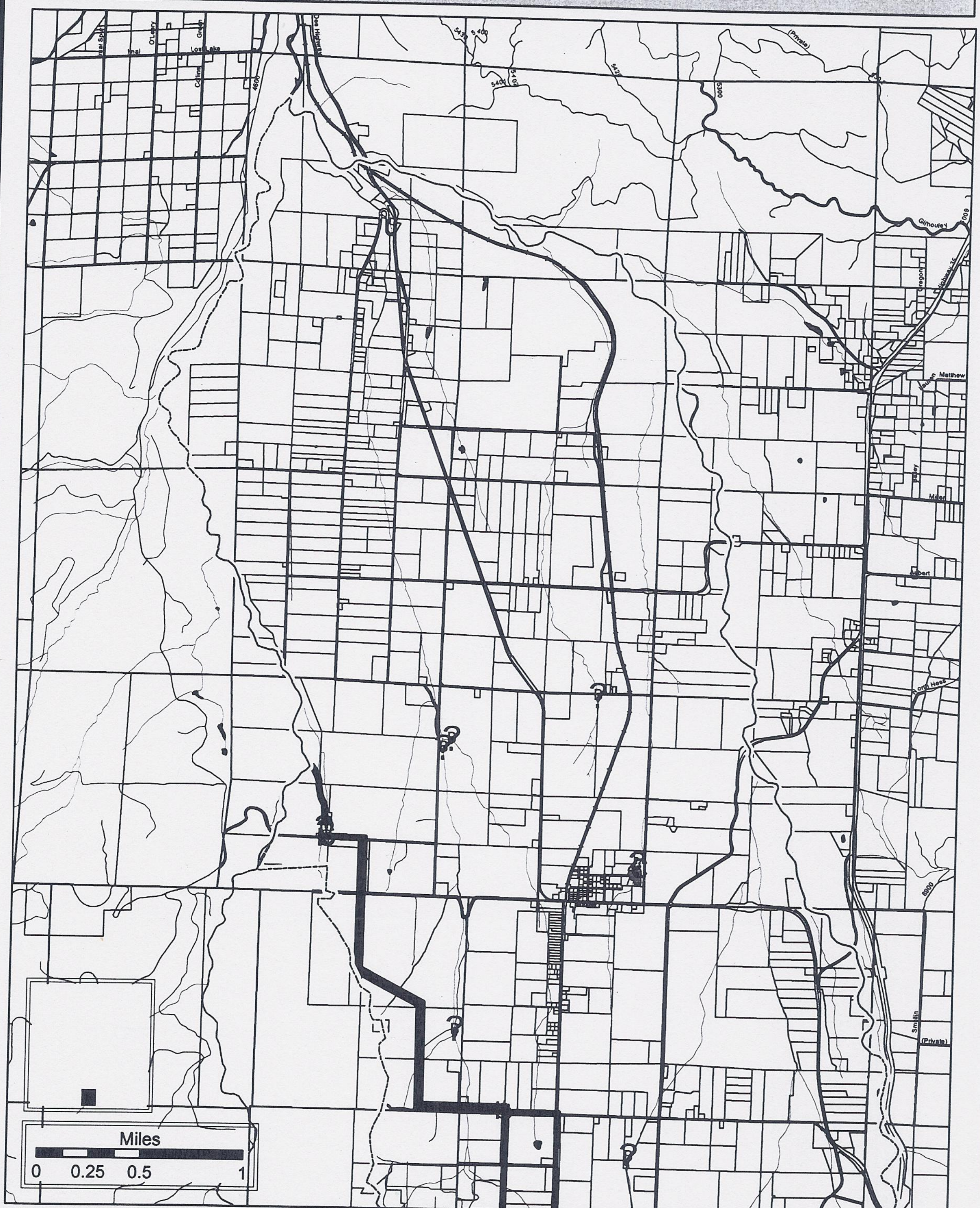

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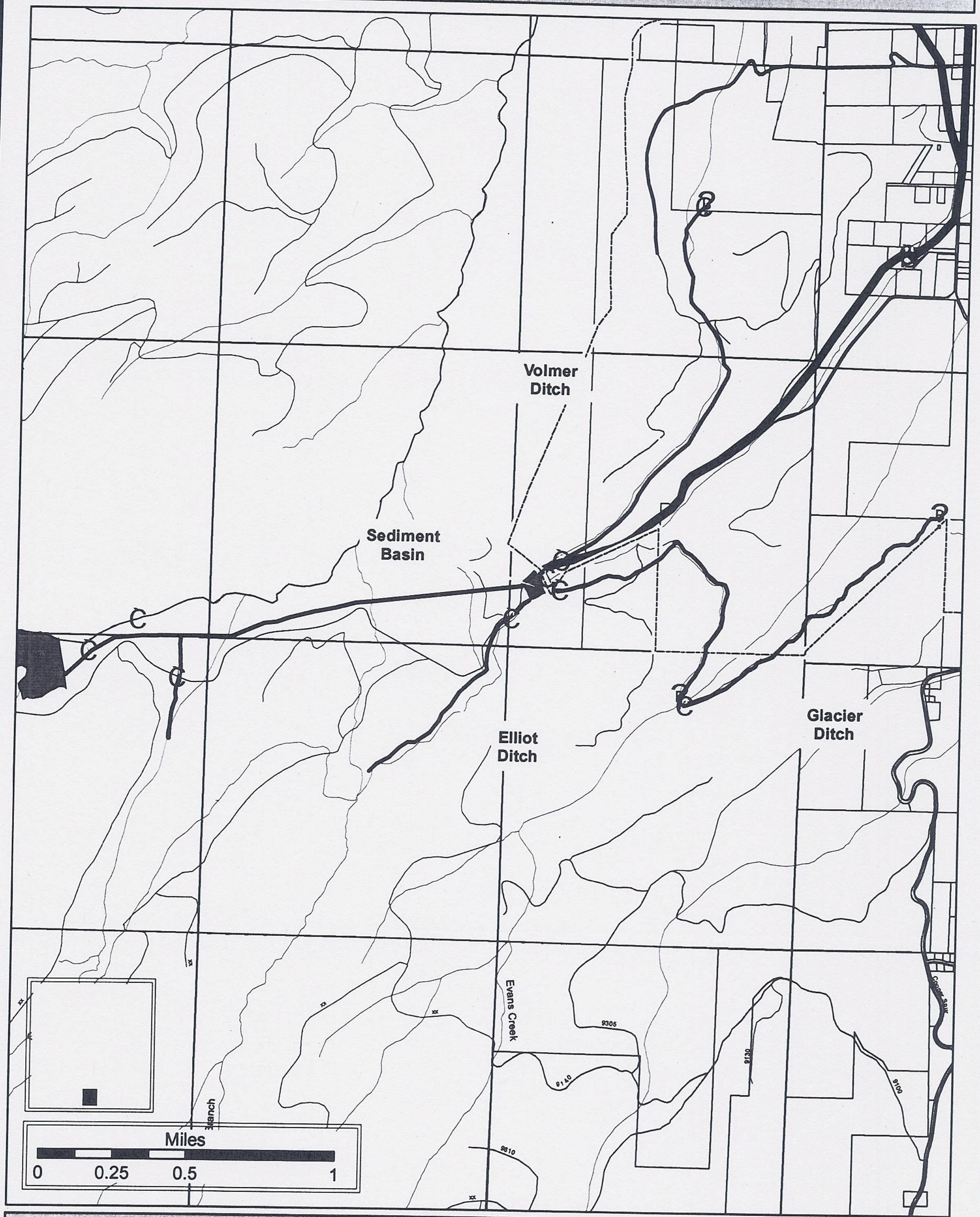

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