YAKIMA RIVER BASIN WATER ENHANCEMENT PROJECT

WASHINGTON

KACHESS LAKE AUGMENTATION

DRAFT STATUS REPORT

BUREAU OF RECLAMATION

UPPER COLUMBIA AREA OFFICE
YAKIMA WA

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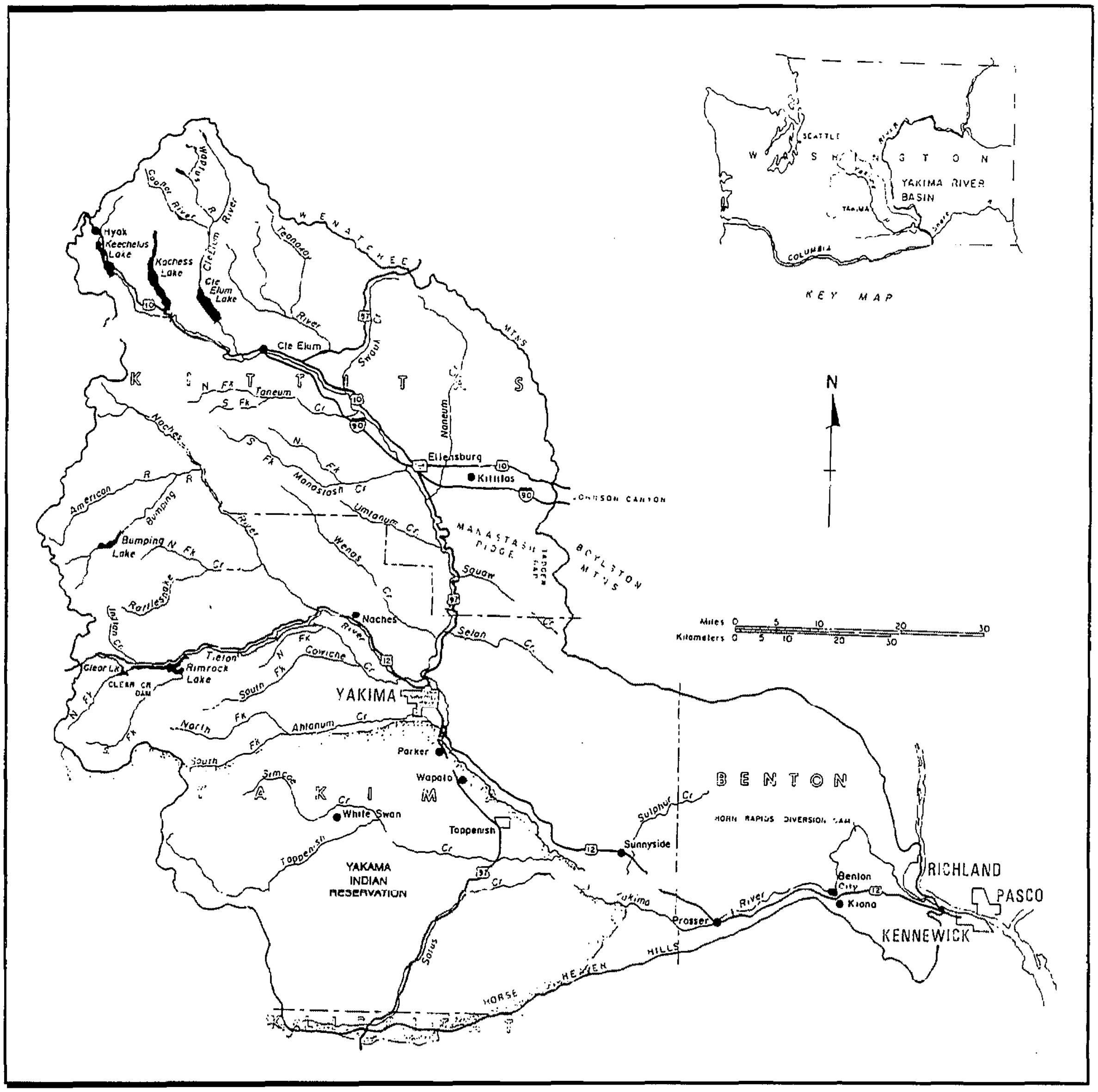
DEPARTMENT OF THE INTERIOR'S MISSION

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering wise use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

RECLAMATION'S MISSION

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.



General Location Map — Kachess Dam and Lake, Yakima River, Washington

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SUMMARY AND CONCLUSIONS

SUMMARY

This draft report provides preliminary hydrology and cost information on the potential for augmenting storage in Kachess Lake with diversions from Cabin and Silver Creeks. This study item was authorized as a potential action under Title XII of Public Law 103–434, which was approved on October 31, 1994. A 1989 study by CH2M Hill, Inc. briefly evaluated this potential based on a simple comparison of runoff and storage capacity to identify the possible water supply increase.

Hydrology studies are the key to assessing this potential. Reclamation used the Yakima River Digital Planning Model to simulate monthly flows for evaluation. A baseline model run (current condition) and two model runs with different levels of augmentation diversions were compared to determine changes in the total water supply available using a 69-year period of analysis (1926–94). One model run — Without Fish Flushing Flows — assumes that flows from Cabin and Silver Creeks would be diverted whenever water is available. A second model run — With Fish Flushing Flows — assumes that flows would not be diverted from Cabin and Silver Creeks during the months of April, May, and June to allow the natural flows of the creeks to contribute to Yakima basin flushing flows. Both options assume that diversions would not begin until flows exceed 50 cubic feet per second (cfs) in Cabin Creek and 10 cfs in Silver Creek. The maximum diversion rate would be 200 cfs from Cabin Creek and 50 cfs from Silver Creek.

Two correlations were made between monthly data and available daily flow data as part of a procedure to refine the results of the monthly model. The procedure was applied to the Cabin Creek and Silver Creek diversions derived in the monthly model runs to provide a more realistic estimate of the increased water supply.

The Bureau of Reclamation prepared an updated cost estimate based on the general layout of facilities developed by CH2M Hill. Reclamation found that the estimated capital cost of the facilities would be about $12.2 million (July 1995 price level). This estimate does not include an allowance for mitigating environmental impacts. Estimates of financing costs and annual operating costs were not prepared.

FINDINGS

During years of proration (15 of 69 years), the average annual increased water supply would be 15,400 acre-feet without fish flushing flows and 10,700 acre-feet with fish flushing flows. Augmentation has a greater effect in years of proration, because Kachess Lake is less likely to fill and spill in those years. The first water to spill from Kachess Lake would be augmentation water which is then lost from the increased water supply. The increased water supply volumes are measured at Kachess Lake and do not reflect any losses during conveyance to sites of use and distribution system operational spills.

Dividing the estimated capital cost of $12.2 million by the estimated average annual increased water supply for the total period of 69 years results in a cost of about $1,580 per acre-foot without fish flushing flows and $2,260 per acre-foot with fish flushing flows. The $12.2 million does not reflect costs associated with financing construction, environmental mitigation, and annual operation and maintenance.

No significant fish benefits were identified for this project. As a result, all costs for augmenting Kachess Lake storage would be allocated to irrigation.

SUMMARY TABLE		
Item	**Without Fish Flushing Flows**	**With Fish Flushing Flows**
Average increase in annual water supply (1926–94 period of analysis)		
Proration years (15)	15,400 acre-feet	10,700 acre-feet
Total period (69)	7,700 acre-feet	5,400 acre-feet
Total cost of facilities*	$12.2 million	$12.2 million
Total cost per acre-foot**	$1,580	$2,260
* July 1995 price levels ** Based on total period		

CONCLUSIONS

Reclamation concludes that:

- Augmenting Kachess Lake storage would benefit irrigation only; no significant fish benefits were identified.
- Benefits to irrigation would be greatest during periods of proration.
- Augmentation with diversions during the spring flushing period of April, May, and June (Without Fish Flushing Flows) would provide a greater amount of water but is unlikely to be acceptable to fishery interests.
- Costs for financing construction, currently unidentified environmental mitigation measures, and annual operation and maintenance costs would increase the cost of the potential measures.

BACKGROUND

PURPOSE AND AUTHORITY

This draft report was prepared to document the Bureau of Reclamation's (Reclamation) evaluation of the Kachess Lake augmentation proposal and provide an opportunity for interested entities to comment on the proposal.

This study item was authorized as a potential action under Title XII of Public Law 103–434, which was approved on October 31, 1994. Section 1209 of the law addresses augmenting storage in Kachess Lake using flows from Cabin and Silver Creeks which are "excess to system demands" and authorizes appropriation of funds for a feasibility study of the measure. One purpose of the study is to identify whether or not the augmented storage would enhance propagation of anadromous fish in the reach of the Yakima River between Easton Diversion Dam and Keechelus Dam. Another purpose is to identify how much additional water could be made available to the Kittitas Reclamation District (KRD) and/or the Roza Irrigation District (RID). If the measure is implemented, the portion of the costs allocated to fishery enhancement would be a Federal cost and the portion of the costs allocated to irrigation would be paid by KRD and/or RID.

LOCATION

The headwaters of the Yakima River are in central Washington, in northwest Kittitas County on the east flank of the Cascade Mountains. The Kachess River flows into the upper Yakima River at river mile (RM) 203.5 and drains an area of about 64 square miles. Kachess Dam was constructed at the outlet of a natural lake to impound a larger Kachess Lake, one of the five major reservoirs of the Yakima Project.

The Kachess River subbasin ranges in elevation from about 6200 feet at the Three Queens peaks on the Chikamin Ridge to 2204 feet at the base of the dam. Precipitation averages about 40 inches a year, mostly as snow that begins falling in early October and usually remains into mid- to late June. Temperatures are cool with an annual average of 40 degrees Fahrenheit.

Cabin Creek drains an area of 28 square miles southwest of Kachess Dam. The 10-mile-long stream flows northeasterly to the confluence with the Yakima River (on the south side), near RM 205. Silver Creek, immediately to the east of Kachess Lake, drains an area of 5 square miles. Flowing south, Silver Creek joins the Yakima River on the left (north) side about RM 201.9, downstream from Easton Diversion Dam.

EXISTING FACILITIES

Completed in 1912, Kachess Dam is a zoned earthfill structure impounding a lake with an active capacity of 239,000 acre-feet and a surface area of 4,540 acres at a normal water surface elevation of 2262 feet. The dam was constructed about ½-mile downstream from the natural lake (see figures 1 and 2 for configuration of original facilities). The crest length is 1,400 feet at elevation 2268 feet with a crest width of 20 feet. The structural height is about 115 feet (as measured from the crest to the base of the cutoff wall).

In 1936, a new spillway was constructed on the right (west) abutment of the dam and is controlled by a 50-foot-wide by 8-foot-high radial gate. The old spillway, which was located on the left (east) side of the dam, was converted to a dike. Over the years, a number of repairs and modifications were made to the dam. These include repairs to the gate hoist system, trashracks, and the outlet works tunnel floor.

In 1996, the original open channel and outlet tunnel complex was cleaned, enlarged, and lengthened to bypass the tunnel section, which was abandoned. These modifications allow increased discharge capacity at low lake levels. Also in 1996, the original intake tower was demolished; a replacement intake tower and control house is under construction and is scheduled to be completed in 1997. The floor of the outlet conduit through the dam was also rehabilitated.

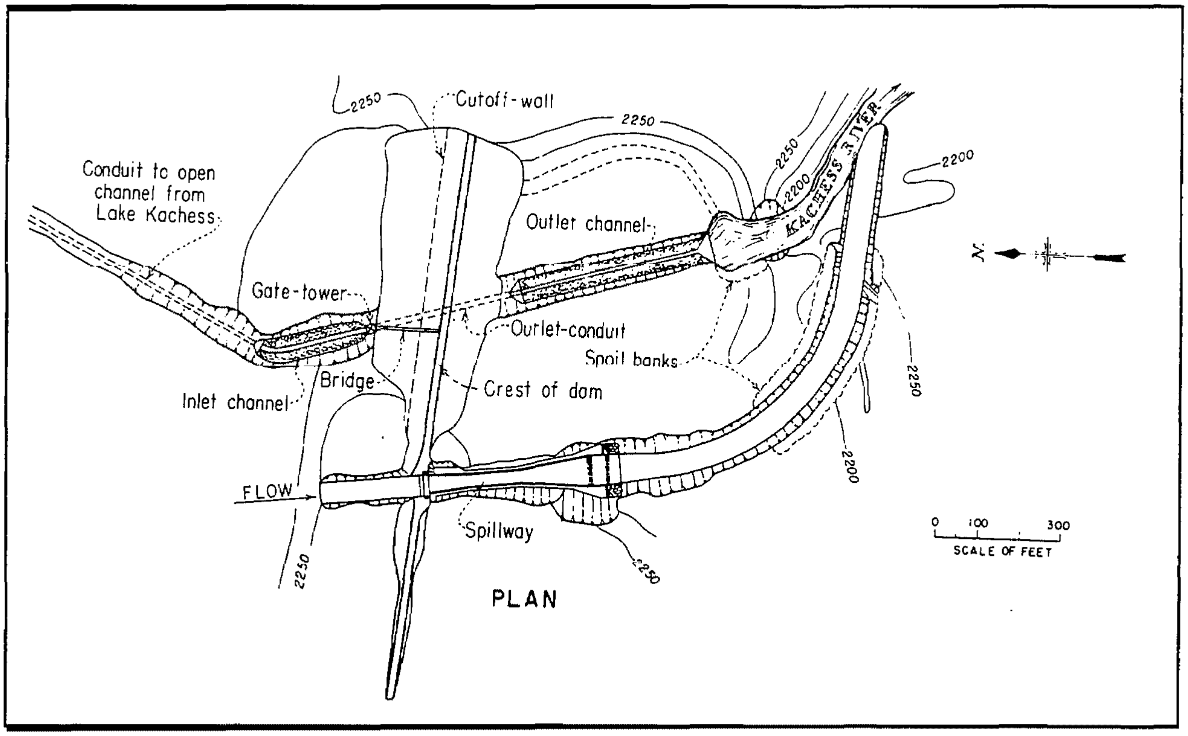

Figure 1. Plan of outlet system of Kachess Dam and Lake prior to 1996 cleaning and enlargement of the in-lake open channel and closure of the in-lake "conduit" (pipeline).

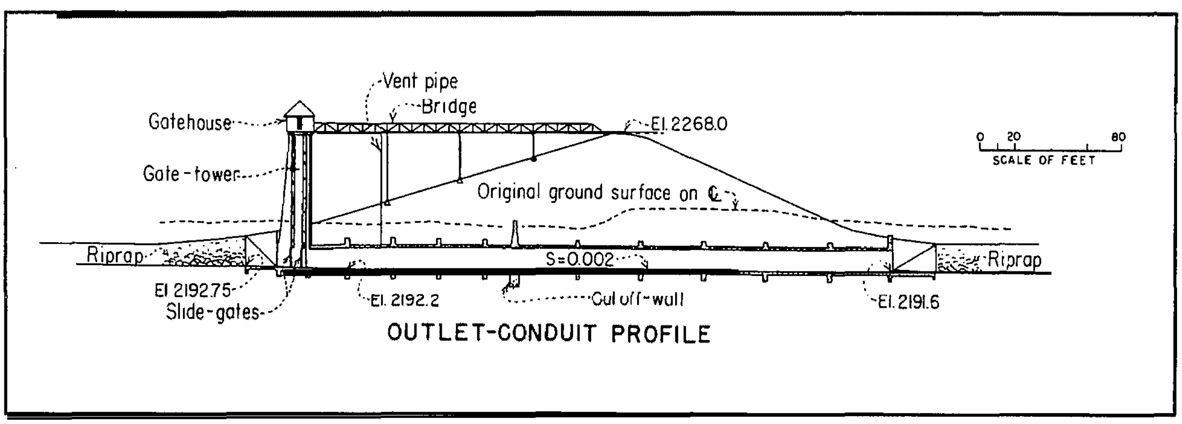

Figure 2. Profile of outlet-conduit, Kachess Dam and Lake prior to 1996–97 replacement of gate tower.

PREVIOUS STUDY — CH2M HILL REPORT

In 1989, CH2M Hill, Inc. evaluated the possibility of transporting water by pipeline from Cabin and Silver Creeks to Kachess Lake.† CH2M Hill concluded it was feasible to annually divert about 35,000 acre-feet from Cabin Creek; water would be diverted only when creek flows exceeded 40 cfs. That estimate was based on flows from March 1–June 15 over a 3-year period (1987–89) in Cabin Creek. CH2M Hill estimated that about 10,000 acre-feet could annually be diverted from Silver Creek but did not allow for a minimum flow in Silver Creek.

CH2M Hill estimated that Kachess Lake had an average annual "excess capacity" (average unfilled capacity) of about 41,000 acre-feet based on the watershed average annual discharge (198,000 acre-feet) at the dam and a reservoir capacity of 239,000 acre-feet.

CH2M Hill noted the reservoir had been operated in such a way that 100,000 acre-feet (or more) was "carried over" 30 out of 43 years in the study period. The report said such an operation recognized the inadequacy of the Kachess watershed to refill the reservoir. In water-short years, there is usually more than 90,000 acre-feet of available storage capacity in the reservoir (based on average end-of-year contents). This space could be available to store water diverted from Cabin and Silver Creeks.

POTENTIAL CABIN CREEK DIVERSION FACILITIES

Cabin Creek Diversion Dam — The concrete diversion dam and gated intake structure would be located about 6,000 feet upstream from the mouth of the creek. The length of the dam would be about 345 feet, the structural height would be about 20 feet, and the overflow spillway would be 320 feet long with a 10-foot-wide crest at elevation 2342 feet. Sixteen 3-foot-high flashboards, 20 feet long, would raise the water level for diversion. The intake structure would be on the right side of the dam. The design would minimize the effects of debris and sediment. The intake weir would be protected from large, floating debris by a bar screen; floating debris less than 6 inches in size would pass through the pipeline and cause no damage.

Cabin Creek Pipeline — The buried gravity pipeline would be about 19,000 feet long. Vents and drains would be installed as needed. As shown in figure 3, the pipeline alignment from the diversion dam would be:

- North about 6,400 feet to the Burlington Northern Santa Fe Corporation (BNSF) railroad tracks
- Thence eastward about 1,500 feet along the south side of the BNSF tracks
- Thence northwest, over a distance of about 800 feet, where it would enter a tunnel beneath the BNSF tracks (to be constructed as part of the project)

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† CH2M Hill, Inc. 1989. *Appraisal Assessment of Augmenting Kachess Reservoir Stored Waters by Gravity Feed from Cabin Creek and Silver Creek.* October 1989. Prepared for Pacific Northwest Region, Bureau of Reclamation by CH2M Hill. Yakima Office, Yakima WA.

- After exiting the tunnel, the pipeline would span the Yakima River on a pipe bridge (to be constructed as part of the project) at a sufficient height to be safe from flood flows
- Thence east about 3,000 feet on the north side of the river, along the former Milwaukee Railroad corridor (the State-owned John Wayne Pioneer Trail)
- Thence north and northwest about 4,000 feet through a privately owned clear-cut, parallel to the border of Easton State Park, to Interstate 90 (I-90)
- Thence north about 800 feet passing underneath I-90, through two existing "grade separation structures" (underpasses) located about 1,500 feet west of the Kachess River
- Thence north about 2,200 feet discharging into Kachess Lake near the right abutment of Kachess Dam

POTENTIAL SILVER CREEK DIVERSION FACILITIES

Silver Creek Diversion Dam — The Silver Creek diversion dam would be located about 1¾ miles east of Kachess Dam (in section 35 of T21N R13E) on privately owned timberlands near an existing wooden diversion structure.

The crest of the concrete dam would be at elevation 2440 feet. The dam crest would be about 40 feet long and 8 feet wide. The gated pipeline intake structure on the right (west) side of the dam would be 6 feet wide by 12 feet long. Large floating debris would be excluded from the pipeline by a heavy bar screen at the intake weir. Debris smaller than 4 inches would pass through the screen and pipeline and should cause no problems. A slide gate on the right side of the crest could be opened to allow floating debris and bedload sediment to be sluiced past the structure.

Silver Creek Pipeline — The buried pipeline would be about 4,800 feet long. The pipeline would be on a continuous downgrade, so air vents and drains should not be necessary.

The outlet would discharge into Kachess Lake near the left abutment of Kachess Dam at about elevation 2262 feet. As shown in figure 3, the pipeline alignment from the diversion dam would be:

- South-southwest for about 450 feet
- Thence west for about 3,000 feet, following an existing logging road
- Thence at a point where the road bears south, the pipeline would continue west to the discharge point into the lake.

IMPLEMENTATION COSTS

CH2M Hill estimated that the cost of constructing the Cabin Creek diversion dam and pipeline was $10.4 million (1990 price level). The total estimated cost of the Silver Creek diversion dam and pipeline was $1.13 million (1990 price level). CH2M Hill did not estimate the annual operation and maintenance costs, financing costs, or environmental mitigation costs.

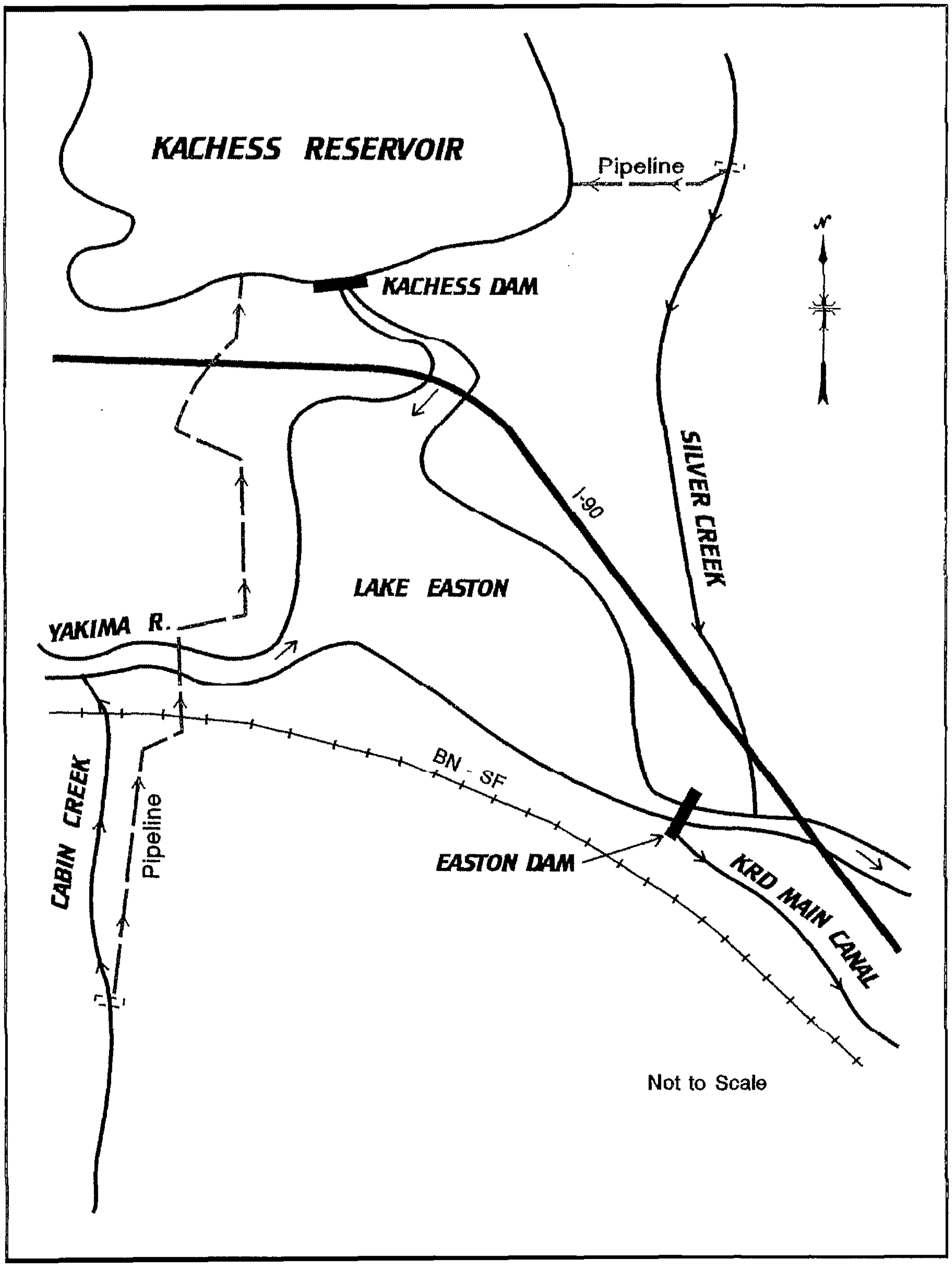

Figure 3. Potential Pipeline Alignment

RECLAMATION ANALYSES

INTRODUCTION

In 1996, Reclamation performed hydrologic analyses at a greater level of detail using a computer simulation to provide an improved assessment of potential augmentation water. These computer modeling studies examined two options — Without Fish Flushing Flows diverted water when available throughout the year and With Fish Flushing Flows preserved streamflow during a critical 3-month period (April, May, and June). Minimum instream flows were maintained in both creeks in both options. After the computer model runs were completed, correlations of a sample of actual daily flows with estimated monthly flows were made. The correlation factors were applied to the monthly computer simulations as part of a procedure to achieve improved estimates. The final results reflect the estimate of increased water supply in the entire 69-year period of study and in prorated water years.†

MODEL ASSUMPTIONS

This analysis is based on computer simulations that use a monthly model — the Yakima River Digital Planning Model (YRDPM). The base computer study set Easton target flows at 100 cfs for the October through February period and at 200 cfs for the March through September period.

The period of analysis for this study is 1926–94. The period from 1970 to 1994 (not including 8 water-short years when proration was in effect)†† was used to establish the average amount of water diverted to supply the current level of development.

The Without Fish Flushing Flows option was predicated on diversion of water from Cabin and Silver Creeks whenever flows and storage space are available. The With Fish Flushing Flows option is similar but does not allow diversion from the creeks in April, May, and June.

The model includes Kachess Lake rule curves and restricts diversions so that water is not diverted from the two creeks to Kachess Lake and spilled in the same month. Based on professional judgement, significant icing would not occur when flows are available for diversion as described below.

For purposes of the YRDPM:

- **Conveyance** is flow which can be diverted from Cabin and Silver Creeks under the monthly model parameters listed below.

† Proration is used when supplies are insufficient to provide full delivery to all water-right holders and is based on the 1945 Consent Decree under which some water rights holders receive a full supply and others receive a proportionate distribution of the remaining available water.

†† 1973, 1977, 1979, 1987–88, and 1992–94.

The following parameters are used in the monthly model:

- Silver Creek flows are about 19 percent of Cabin Creek flows based on a ratio of the drainage area sizes.
- Water will not be diverted from Cabin Creek if flows are less than 50 cfs nor from Silver Creek if flows are less than 10 cfs; these levels reflect input from fish biologists and were not fully allowed for in the CH2M Hill evaluation.
- The maximum conveyance rates, based on professional judgement of water availability versus cost-effective pipe sizing, are 200 cfs from Cabin Creek and 50 cfs from Silver Creek.
- Water will be diverted only if storage space is available in Kachess Lake in the same month.

MODIFIED VALUES

For purposes of the modified values process:

- **Availability** is Conveyance reduced (by the factor discussed below) to correct for the monthly model overestimating water available for Conveyance.

- **Diversion** is Availability reduced by the need to meet target flows at Easton and Parker and an initial estimate of diversions that would be spilled from Kachess Lake in subsequent months if diverted.

- **Increased Water Supply** is Diversion reduced to account for the final estimate of diversions spilled from Kachess Lake.

The Conveyance values derived from the YRDPM model were modified because of concerns that a monthly model tends to overestimate the water available on a daily basis. The modified monthly values resulted from a hydrologic analysis involving a four-step procedure that considered:

- 1. Physically available flow based on daily values
- 2. A constraint to avoid diverting water that may be needed to meet target flow requirements at Easton and/or Parker
- 3. A constraint to limit diverting water that may be spilled in subsequent months based on a forecast of whether or not the lake will fill
- 4. A computation of Increased Water Supply after accounting for spill of allowed Diversion as a result of actual, natural inflow to the lake

Actual 1987–94 daily Cabin Creek flows which exceeded the 50 cfs instream flow requirement and were less than the maximum diversion rate of 200 cfs were converted to acre-feet and summed for each month. Those monthly totals were compared to the computer-simulated monthly Conveyance values. The results showed that the monthly model estimated higher Conveyance values than resulted from summing daily flows. The correlation of summed daily flows with monthly flows was performed (see attachment A) and a "factor" of 0.84 was developed. The YRDPM monthly Conveyance values were reduced by using the 0.84 factor to calculate Cabin Creek Availability values. This same factor was applied to the Silver Creek Conveyance values to estimate Silver Creek Availability values.

Diversion values were then computed by applying a compound factor to the Availability values. This compound factor was developed to limit diversions based on an initial forecast of remaining Kachess Lake storage space and the need to meet target flows at Easton and Parker. The target flow portion of the compound factor is a three-variable, regression correlation used to constrain diversions when flow at Easton is less than or near the target flow, or when flow at the Parker control point at RM 104 is less than or near the target flow plus an operational buffer (see attachment A).

Finally, Diversions to Kachess Lake that were later spilled in the same year were subtracted from the total annual diversion, resulting in the Increased Water Supply values.

RESULTS

Without Fish Flushing Flows, the Increased Water Supply would average 7,700 acre-feet for the entire 69 year period of study and 15,400 acre-feet in prorated years.

With Fish Flushing Flows (no diversions in April, May, and June), the Increased Water Supply would average 5,400 acre-feet for the entire 69-year period of study and 10,700 acre-feet in prorated years.

The modification procedure produces estimates of Increased Water Supply that are significantly less than the Conveyance values derived by the monthly model simulation. However, it provides a more realistic estimate of how the system would likely be operated with the augmentation facilities in place.

The monthly model Conveyance results and the modified values are shown in table 1. Results With and Without Fish Flush Flows for the period 1926–1994 are shown in Attachment B.

Table 1. Average Annual Conveyance, Availability, Diversion, and Increased Water Supply
(acre-feet; period of analysis 1926–94)

	Monthly Model*	**Modified Values**		
	Conveyance	**Availability**	**Diversion**	**Increased Water Supply**
Option 1. Without Fish Flushing Flows				
Period of record	27,000	22,700	14,700	7,700
Prorated years†	24,000	20,200	15,400	15,400
Option 2. With Fish Flushing Flows ‡				
Period of record	20,400	17,100	11,800	5,400
Prorated years†	16,800	14,100	10,700	10,700

* Operational spill not accounted for in monthly model
† 1926, 1929-31, 1940-42, 1944-45, 1977, 1987-88, 1992-1994
‡ No diversions allowed April through June

FURTHER HYDROLOGIC ANALYSIS

This study is appraisal level, so the development of a daily database and model for the whole period of analysis was not undertaken. The methodology used was consistent with the level of detail required to understand the range of flows available from Cabin and Silver Creeks. If the augmentation study is continued to the feasibility level, a daily data base and model would be considered to refine the analyses.

IMPLEMENTATION COSTS

Cost curves based on diversion capacity from the two creeks were developed for this study. These cost curves included only capital costs. Costs relating to possible environmental mitigation measures, financing (interest during construction), and the annual costs of operation and maintenance are not included. Reclamation estimates the facilities capital cost at about $12.2 million (July 1995 price level).

UNRESOLVED CONCERNS

An economic analysis of the augmentation proposal has not been prepared. However, hydrologic analyses have not identified any opportunities for the proposal to significantly enhance fishery flows in the Keechelus to Easton reach of the Yakima River. As a result, all costs for augmentation of Kachess Lake storage would be allocated to irrigation.

Detailed environmental analyses have not been performed. However, concerns have been raised over project impacts on system flushing flows and the potential for siltation impacts on recently modified Kachess Lake outlet channel. Measures necessary to mitigate construction impacts have not been identified at this time.

ATTACHMENTS

ATTACHMENT A

DEVELOPMENT OF MODIFICATION FACTORS

Conveyance of Water from Cabin and Silver Creeks

Beginning with the physical availability of water from the two creeks, there was concern that the monthly model allows more water to be moved than would actually be available on a daily basis because of the nature of the watersheds and the minimum flow and maximum diversion rate constraints imposed on the model. This concern was addressed by correlating Cabin Creek 1987–1994 historical monthly flow with historical daily flow summed to monthly using the same model parameters used in the YRDPM. The correlation resulted in an R-squared† of 0.96 and verified that, on a daily basis, about 16 percent less water would be available than would be estimated by relying on the monthly values alone. Thus, a factor of about 0.84 is used to reduce the Conveyance calculated by the monthly model to compute Availability values. The correlation was performed on Cabin Creek flows and applied to flows from both Cabin and Silver Creeks (Silver Creek flows are estimated to be about 19 percent of Cabin Creek flows based on a comparison of the drainage area sizes).

Diversion Constraint, Easton and Parker Target Flows

There is a similar concern over providing Easton and Parker target flows on a daily basis compared to the monthly analysis. The monthly model correctly maintains flows used to meet targets at Easton and Parker as separate and distinct from diversions to Kachess Lake. The monthly model allows diversions to Kachess Lake only when the amount of water required to meet target flows is available elsewhere in the system. However, if in actual operations, the ability to satisfy target flows is marginal, particularly as analyzed on a monthly basis, the diversion would probably not occur continuously, but would be adjusted periodically within a month to maintain the target flows. Thus, average monthly amounts could be higher than if daily values are summed to calculate monthly values.

This concern was addressed by using 1987–1994 historical daily target and measured flow values for Easton and Parker to create a monthly "Observed Easton-Parker Factor." A monthly "Synthetic Easton-Parker Factor" was generated by correlating three independent variables using monthly historical values at Easton and estimated values at Parker. The intent was to have the ability to use monthly modeled flows at Easton and Parker to predict the percent of days within each month that Availability flows could be diverted.

The first of the three independent variables is the computed Easton Ratio, which is monthly flow at Easton divided by a threshold value. Similarly, the second variable is the computed Parker Ratio,

† R-squared is a coefficient that indicates the degree of correlation between sets of data

which is monthly flow at Parker divided by a threshold value. Each of these ratios ranged from zero to one. An operational target was computed at Easton equal to the target flow, and at Parker equal to the target flow plus 100 cfs (to allow a buffer for operation to be practicable). Flows less than the operational target received a ratio of zero and flows greater than a threshold value of three times the operational target were assigned a ratio of one. Flows between those limits (the operational target and the threshold) were divided by the respective threshold value to generate a ratio between zero and one.

The third variable used in the correlation was the product of the Easton Ratio and the Parker Ratio. This variable was intended to represent the cross-dependency that may exist between the two locations while physically operating to meet both targets.

The correlation between Observed and Synthetic Easton-Parker Factors was made using the historical Easton target and estimated historical Parker target flows (with a 100-cfs operational buffer) resulting in an R-squared value of 0.82. Coefficients for the three independent variables were used to compute the Synthetic Easton-Parker Factor.

The correlation resulted in the following computation:

(0.27) x (computed Easton Ratio)
+ (0.84) x (computed Parker Ratio)
– (0.11) x (computed Easton Ratio) x (computed Parker Ratio)

= Synthetic Easton-Parker Factor

The Easton Ratio depends on a fixed monthly distribution of target flow, while the Parker Ratio is dependent on target flows that now vary with Total Water Supply Available. The modeled monthly target and flow values at Easton and Parker, and the threshold values described above were used to generate the three computed independent variables. Through application of the equation, the Synthetic Easton-Parker Factor was computed, which was used as an estimate of the fraction of days within each month that the modeled monthly flow values would exceed the modeled monthly target flows at Easton and Parker. The Synthetic Easton-Parker Factor is one part of a compound factor used to constrain Diversion of Cabin and Silver Creek Availability.

Diversion Constraint, Kachess Lake Storage

The monthly model considers storage remaining at Kachess Lake during the current month in the computation process. If the reservoir fills at any time during a year under the base condition (no augmentation), the benefit of augmentation for that year would be zero; augmentation in that year would result in a spill and the first water spilled would be that gained from augmentation.

This is a conservative approach in some years because with diversions from Cabin Creek and Silver Creek available, the carryover storage in the watershed could shift in location between reservoirs. This would potentially allow a heavier draft on Kachess Lake to meet demands, the net effect being less spill of the Cabin Creek and Silver Creek diversions and consequently greater use of those diversions.

A method was needed to forecast, in an operationally practicable manner, whether to proceed with augmentation throughout the year. This concern was addressed by applying two checks to the potential diversions based on storage levels at Kachess Lake. Diversions were made October through December. The end-of-December Kachess Lake contents (storage) were then compared to a cutoff value determined by trial-and-error to decide whether to allow diversion in the next month. Similarly, end-of-January and end-of-February Kachess Lake contents were compared to decide whether to allow diversion in the months of February and March. For the Without Fish Flows alternative (which allowed diversion April through June), the process was continued by use of end-of-March, end-of-April, and end-of-May Kachess Lake contents to determine whether to allow diversion in the following months of April, May, and June, respectively. This method resulted in the other part of the compound factor used to reduce Availability to Diversion.

Increased Water Supply

Such instances of diversion and spill as described above should be realistically expected to occur, so the loss of benefit should be accounted for. The content tables were then examined for a base fill condition. If Kachess Lake filled at any time during a year under the no augmentation condition, then all diversion for that year was spilled. Or, if the reservoir came within the diversion amount of filling in the no augmentation condition, the excess or difference between diversion and remaining storage was spilled. In either case, the amount spilled was not included in Increased Water Supply. The intent was to get a realistic idea of what would actually be diverted, how much would later be spilled, and the resulting Increased Water Supply.

ATTACHMENT B

Increased Water Supply Without and With Fish Flushing Flows, 1926–94
(acre-feet)

Year	Space Available in Kachess (from base condition)	Option 1. Without Fish Flushing Flows			Option 2. With Fish Flushing Flows		
		Total Diversion	Diversion Spilled	Increased Water Supply	Total Diversion	Diversion Spilled	Increased Water Supply
1926	55,500	17,643	0	17,643	17,643	0	17,643
1927	50,300	20,969	0	20,969	13,500	0	13,500
1928	0	3,753	3,753	0	4,410	4,410	0
1929	79,000	630	0	630	630	0	630
1930	147,100	17,341	0	17,341	8,096	0	8,096
1931	113,200	6,935	0	6,935	3,412	0	3,412
1932	5,900	33,998	28,098	5,900	16,638	10,738	5,900
1933	0	8,543	8,543	0	8,543	8,543	0
1934	0	66	66	0	66	66	0
1935	0	23,343	23,343	0	23,343	23,343	0
1936	0	13,052	13,052	0	2,503	2,503	0
1937	33,100	9,094	0	9,094	1,089	0	1,089
1938	0	8,972	8,972	0	8,968	8,968	0
1939	21,300	12,980	0	12,980	15,715	0	15,715
1940	66,500	13,909	0	13,909	8,637	0	8,637
1941	160,200	9,219	0	9,219	3,586	0	3,586
1942	113,600	19,129	0	19,129	15,620	0	15,620
1943	37,400	37,352	0	37,352	23,781	0	23,781
1944	65,300	11,254	0	11,254	11,078	0	11,078
1945	97,200	25,150	0	25,150	23,179	0	23,179
1946	19,900	35,033	15,133	19,900	19,465	0	19,465
1947	0	12,879	12,879	0	12,879	12,879	0
1948	0	24,333	24,333	0	24,333	24,333	0
1949	0	10,946	10,946	0	10,946	10,946	0
1950	0	12,149	12,149	0	12,149	12,149	0

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Year	Space Available in Kachess (from base condition)	Option 1. Without Fish Flushing Flows			Option 2. With Fish Flushing Flows		
		Total Diversion	Diversion Spilled	Increased Water Supply	Total Diversion	Diversion Spilled	Increased Water Supply
1951	0	3,005	3,005	0	3,005	3,005	0
1952	8,300	8,911	611	8,300	8,911	611	8,300
1953	2,900	24,024	21,124	2,900	24,024	21,124	2,900
1954	0	12,879	12,879	0	12,879	12,879	0
1955	0	3,680	3,680	0	3,680	3,680	0
1956	0	5,074	5,074	0	5,074	5,074	0
1957	0	5,320	5,320	0	5,320	5,320	0
1958	26,900	22,463	0	22,463	18,368	0	18,368
1959	0	15,976	15,976	0	18,759	18,759	0
1960	0	10,873	10,873	0	10,873	10,873	0
1961	0	10,337	10,337	0	10,337	10,337	0
1962	500	6,629	6,129	500	6,629	6,129	500
1963	2,700	17,328	14,628	2,700	17,328	14,628	2,700
1964	0	10,529	10,529	0	9,923	9,923	0
1965	0	2,478	2,478	0	2,478	2,478	0
1966	20,900	22,924	2,024	20,900	675	0	675
1967	0	13,435	13,435	0	26,314	26,314	0
1968	0	7,289	7,289	0	7,289	7,289	0
1969	0	19,268	19,268	0	19,268	19,268	0
1970	0	18,163	18,163	0	5,834	5,834	0
1971	0	120	120	0	12,999	12,999	0
1972	0	7,417	7,417	0	7,417	7,417	0
1973	22,100	3,180	0	3,180	3,180	0	3,180
1974	0	37,673	37,673	0	26,450	26,450	0
1975	0	3,323	3,323	0	3,323	3,323	0
1976	0	2,474	2,474	0	2,474	2,474	0
1977	47,900	8,301	0	8,301	8,301	0	8,301
1978	29,800	24,378	0	24,378	24,378	0	24,378
1979	36,700	19,156	0	19,156	6,411	0	6,411
1980	69,300	26,684	0	26,684	15,527	0	15,527
1981	39,700	19,756	0	19,756	19,756	0	19,756

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Year	Space Available in Kachess (from base condition)	Option 1. Without Fish Flushing Flows			Option 2. With Fish Flushing Flows		
		Total Diversion	Diversion Spilled	Increased Water Supply	Total Diversion	Diversion Spilled	Increased Water Supply
1982	0	25,041	25,041	0	25,041	25,041	0
1983	0	7,215	7,215	0	7,215	7,215	0
1984	0	16,483	16,483	0	16,483	16,483	0
1985	5,100	18,315	13,215	5,100	6,706	1,606	5,100
1986	6,000	12,149	6,149	6,000	12,149	6,149	6,000
1987	42,900	29,304	0	29,304	17,655	0	17,655
1988	107,300	22,841	0	22,841	11,164	0	11,164
1989	61,700	33,803	0	33,803	21,315	0	21,315
1990	0	17,098	17,098	0	24,638	24,638	0
1991	0	0	0	0	0	0	0
1992	28,600	12,690	0	12,690	12,690	0	12,690
1993	103,800	16,725	0	16,725	10,239	0	10,239
1994	131,700	19,898	0	19,898	8,414	0	8,414
Max.		37,673	37,673	37,352	26,450	26,450	24,378
Ave.		14,685	6,961	7,724	11,755	6,322	5,433
Min.		0	0	0	0	0	0