Yakima River Basin Study

Roza and Chandler Power Plants Subordination and Power Usage Evaluation
Technical Memorandum

Bureau of Reclamation
Contract No. 08CA10677A ID/IQ, Plan of Study Task 4.3

Prepared by

HDR Engineering, Inc.

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Columbia-Cascades Area Office

State of Washington
Department of Ecology
Office of Columbia River

July 2011

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1.0 Introduction

As a part of development of the Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan), HDR performed a limited assessment of power usage considerations for actions in the Integrated Plan and subordination of power generation at the Roza and Chandler hydropower plants to support stream flows. The evaluation of subordination was limited to available energy production records provided by the United States Bureau of Reclamation (Reclamation) that generally reflect the current level of subordination. As a part of this assessment consideration has been given to the possibility of replacing the energy produced at the Roza and Chandler hydropower plants with other opportunities for energy recovery within the range of projects being considered.

The Roza and Chandler Power Plants are operated under a current scenario of subordination to leave water in the river for fish passage in lieu of generating power at certain times of year and under certain flow conditions. The probable scenario for future levels of subordination is a subject of ongoing discussions. Simple assumptions regarding subordination at each plant were used in this analysis. The evaluation is focused on energy production without consideration of the value of power production capacity since establishing the value of power capacity generally requires work associated with development of a power purchase agreement and/or a power market analysis that is beyond the scope of this study.

Further subordination of the Roza and Chandler Power Plants will need to be assessed relative to the economic and operational impacts for the Roza and Kennewick Irrigation Districts, Reclamation, and BPA. The implications of further subordination of both plants are similar in some respects including, but not limited to: power production, plant maintenance, and maintenance of conveyance facilities upstream from the power plants. There are also implications that are different for each of the subject power plants. Reduction of power production at the Chandler Power Plant affects the amount of power available for distribution in the power grid and could affect operation and maintenance of the pump turbines used to deliver water to the Kennewick Irrigation District. The implications for reduction of power production at the Roza Power Plant include, but are not limited to: changes in the amount of power being provided from the Roza Power Plant for irrigation district pump stations and less power available in determination of the irrigation district power rates.

New generating facilities associated with actions that have been identified in the integrated plan were considered in this evaluation to determine if these facilities have the ability to offset the potential reduction in energy production caused by subordination of the Roza and Chandler Power Plants. New hydropower plants considered in the course of this review include:

- ***Wymer Reservoir Power Plant*** *(at the inflow point of Wymer Reservoir)*
- ***Wymer-Roza Power Plant*** *(at the point of discharge from Wymer Reservoir to the Roza Canal Headworks)*
- ***Bumping Reservoir Power*** *Plant (at the outlet works for the enlarged Bumping Reservoir)*
- ***Keechelus to Kachess Pipeline Power Plant*** *(at the point of discharge into Kachess Reservoir)*
- ***Kachess Inactive Storage Tunnel Power Plant*** *(at the point of discharge into the Yakima River)*

In addition to these potential hydropower facilities, new pumping stations have been identified, and these would represent new energy demands. Potential new pumping plants under consideration include:

- ***Wymer Pumping Station***
- ***Thorp Pumping Station*** *(if substituted for Wymer Pumping Station)*
- ***Kachess Pumping Station*** *(if substituted for the Kachess tunnel option)*

The Thorp and Wymer pumping stations are alternative to one another, and it is unlikely that both would be constructed. Likewise the Kachess pumping station and Kachess Inactive Storage Tunnel are alternatives to one another, and both facilities would not be constructed. Resolution regarding which of these alternatives are advanced will occur at a later stage of the planning process for the Integrated Plan.

A water balance model developed in support of the Integrated Plan was prepared using the RiverWare program. The output from this model is flow required to satisfy in-stream flow requirements in the Yakima River Basin for the variety of needs that were used to construct the model. These "need" constraints included flows through Wymer Reservoir to meet Roza Irrigation District demands at times when the irrigation demands could not be by river diversions at the Roza Dam without compromising other water use goals.

This technical memorandum presents the results from a limited assessment of these issues that was performed for the Integrated Plan project. Further evaluation will be needed in later stages of planning to examine the cost-effectiveness of constructing and operating additional power generation facilities versus purchasing power instead; as well as the overall economics of the subordination concept.

2.0 Summary of Results

Based on data supplied by Reclamation for power production at both the Roza and Chandler Power Plants from 1988 to 2010, which generally represents the current level of subordination, an average of approximately 107,000 MWH of energy is being produced each year. The Roza Power Plant contributes approximately 61,000 MWH to this total and the Chandler Power Plant supplies the remaining 46,000 MWH.

There have been some discussions considering the possibility of further subordination for biological benefits by not operating the Roza and Chandler Power Plants in the spring. Specifically, the Roza Power Plant would not be used to produce power in April and May and the Chandler Power Plant would not be used to produce power in April, May and June.

Based on the historical data supplied by Reclamation, this would result in an average of approximately 82,000 MWH of annual power from the Roza and Chandler Power Plants – with the Roza plant contributing 47,000 MWH and the Chandler plant contributing 35,000 MWH to that total. This would represent a reduction of 25,000 MWH annually. However a plan for further subordination has not been agreed to by the stakeholders and the estimate of power production may change based on the final duration of time frames for not operating the power plants, the ability to schedule maintenance or replacement activities (that have historically interrupted power production at other times of the year) during the selected time frames, and the need for power at the plants while they aren't producing power (i.e. the plants become a power consumer rather than a power producer).

Energy recovery facilities (hydropower plants), at locations where actions are proposed by the Integrated Plan, provide an opportunity to compensate for the reduced energy production caused by subordination the Roza and Chandler Power Plants. Consideration of the potential to

compensate for subordination includes both energy production at power plants and energy consumption at pumping plants. A study of necessary upgrades to the transmission system, the economics and optimum configuration of the new plants, and the coordination of diversions and power production were beyond the scope of this study. If any of the new facilities are pursued, each will require new agreements with BPA and other power utilities for the purchase or sale and transmission of power.

Table 1 summarizes the overall power balance for projects associated with the Integrated Plan, including power subordination. Energy production and consumption estimates are based on flows developed by the water balance model developed for the Integrated Plan.

Table 1. Power Balance Summary

Energy Production of New Power Facilities	+	115,000 MWH
Energy Consumption to Lift Water into Wymer Reservoir	-	84,000 MWH
Reduced Production from Additional Power Subordination	-	25,000 MWH
Net Effect of Integrated Plan with Additional Subordination	**+**	**6,000 MWH**

Regarding selection of alternatives affecting power production and consumption, the power balance above assumes the Thorp Pumping Station is installed instead of the Wymer Pumping Station; the Kachess Inactive Storage Tunnel option is constructed; and the Kachess Pumping Station is not needed.

Because of the many uncertainties associated with power subordination as well as power production and consumption by new facilities this result is best viewed as showing the overall power balance of the Integrated Plan with power subordination would be roughly neutral (no net change or a small net change) under the assumptions used in this analysis. However many of these assumptions need to be validated and may need to be modified.

The full range of implications associated with increasing the level of subordination has not been fully explored at this time because a preferred project configuration has not been identified. Further consideration of subordination should include a more complete evaluation of impacts and potential benefits in coordination with the Integrated Plan and actions to be implemented.

3.0 Power Subordination

Water is currently diverted from the Yakima River to produce power at Roza and Chandler Power Plants. Power subordination occurs when some or all of the water that could otherwise be diverted for power production is instead left in the river to provide in-stream flow benefits for fish. Reclamation's Yakima Field Office Manager is responsible for operation of the Yakima Project including the timing and amounts of water released from the Project's storage reservoirs. The Project manager consults with Basin interests to determine the appropriate level of power subordination that is needed from time to time to maintain adequate fish and aquatic habitat in the Yakima River system. The Integrated Plan includes a proposal for more power subordination for in-stream flow benefits for fish. The level of this additional subordination is under discussion.

The energy from the Roza Powerhouse provides power for pumping plants in the Roza Irrigation District with any excess power being available to BPA for distribution. Power from the Chandler Power Plant is introduced into the grid for distribution by the Bonneville Power Administration.

3.1 Chandler and Roza Power Plants

The Yakima Project provides irrigation water to the Kittitas and Yakima Valleys. There are seven divisions in the project: Storage, Kittitas, Tieton, Sunnyside, Roza, Kennewick, and Wapato. Storage dams and reservoirs on the project include Bumping Lake, Tieton, Cle Elum, Kachess, and Keechelus. Other project features include diversion dams, canals, laterals, pumping plants, drains, power plants, and transmission lines.

The Roza Division, a unit containing approximately 72,500 acres of land north of the Yakima River, extends from the vicinity of Pomona to a point north of Benton City and is operated by the Roza Irrigation District. The distribution system is supplied by the Roza Canal, which originates at the Roza Diversion Dam on the Yakima River about 10 miles north of Yakima. The Roza Power Plant is adjacent to the Roza Canal, near canal mile 11, and 3 miles east of downtown Yakima.

The Kennewick Division is a combined irrigation and power development. It includes the Chandler Power Plant and over 19,000 acres of irrigable land, of which some 4,600 acres are in the Kennewick Highlands and have been irrigated for many years. The Kennewick Division operated by the Kennewick Irrigation District is the second unit in the Yakima Project to use diverted water for both irrigation and power. Water is diverted from the Yakima River near the town of Prosser at the Prosser Diversion Dam. It is then conveyed ten miles through the Chandler Power Canal to the Chandler Power and Pumping Plant. There, the water is pumped by hydro pumps through a siphon under the Yakima River and lifted 100 feet to the Kennewick Main Canal. The canal travels southeast for 42 miles and the water is used to irrigate 19,171 acres south of the Yakima River. Water in the canal is used to produce power and the energy is sent to the Bonneville Power Administration.

The two power plants, Roza and Chandler, are integral parts of the Roza Irrigation District and Kennewick Irrigation District. The Roza Power Plant was built in 1958 and the Chandler Power Plant in 1956. Both were originally conceived, in part, as a means of paying for the infrastructure making up the Roza and Kennewick Irrigation District combined facilities.

The Roza Plant is a conventional hydroelectric powerhouse with a single propeller style turbine, having a capacity of 12.9 MW. The plant is rated at 158 feet of head, and produces an average annual energy amount approximately 61,000 MWH (based on Reclamation power records from 1988 through 2005), under current subordination practices.

The Chandler Plant is a 12 MW powerhouse with two turbines mechanically coupled to irrigation pumps. The vertical shaft Francis units operate between 106 and 122 feet of head with a rated discharge of 735 cfs. Directly connected to each turbine is a vertical shaft centrifugal pump. Each pump has a rated discharge of 167 cfs, and the pumps are used to lift irrigation water 101.5 feet from the Yakima River into the Chandler canal. When water is not required for irrigation, the turbines can generate additional energy for revenue. The general locations of the existing facilities and are shown in Figure 1.

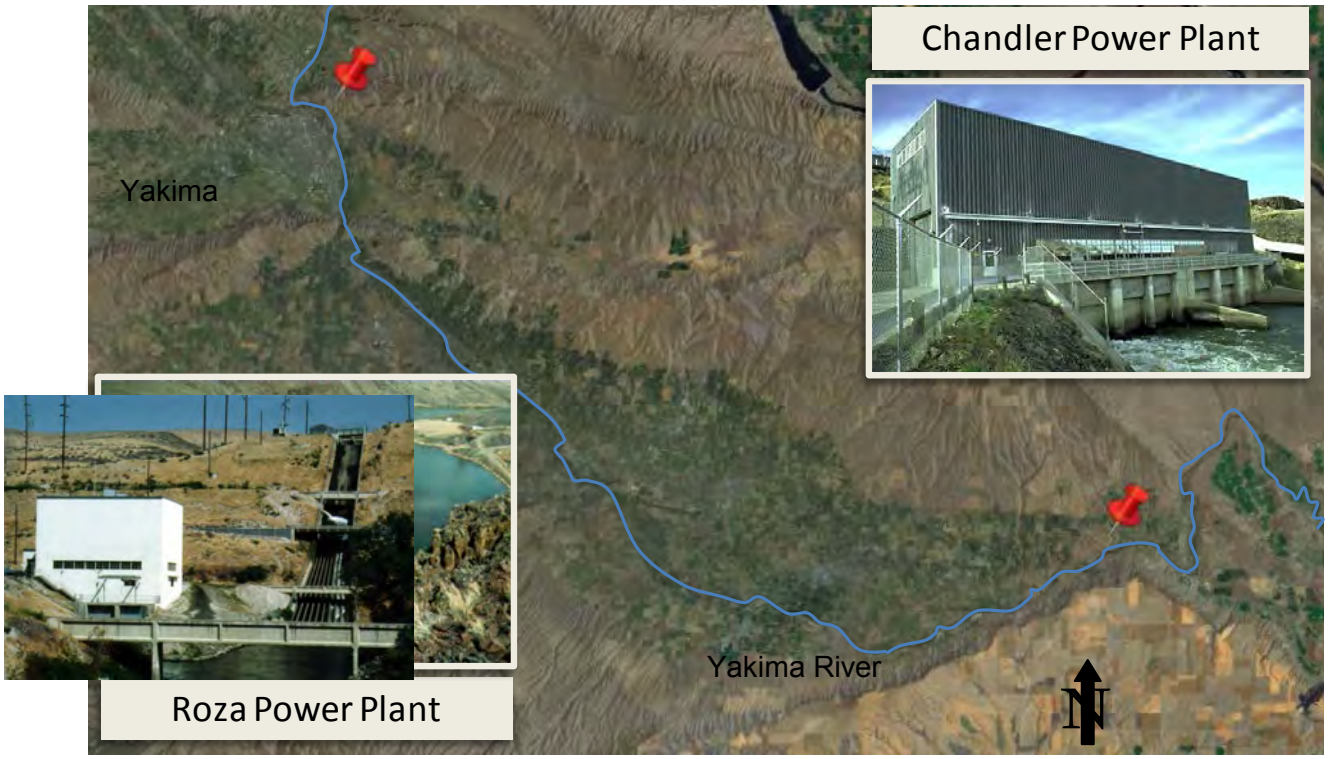

Figure 1. Roza and Chandler Power Plant Locations

3.2 Agency Agreements

The Roza and Chandler Power Plants are operated in compliance with a complex set of parameters related to flow through the plants, value of power, and operation & maintenance costs. The current operation of these power plants represents many years of collaboration between Reclamation, BPA, the Irrigation Districts, and other stakeholders. The Roza and Chandler Powerplants are owned and operated by Reclamation. Power surplus to the needs of Yakima Project operations, including the major pumping plants on the Roza irrigation system, is marketed by the BPA. BPA provides direct funding of operations, maintenance, and equipment replacements costs at the plants. The BPA direct funding replaces funds Reclamation would otherwise have to obtain through federal appropriations processes. Agreements and contracts between Roza Irrigation District, Reclamation, and/or BPA define the direct funding arrangements, Reclamation's obligations with respect to providing pumping power for the Roza facilities, and Roza Irrigation District's project repayment obligations.

The Roza Power Plant is operated and maintained under the Power Shaping Agreement executed by the Department of Energy acting through the Bonneville Power Administration and the Bureau of Reclamation in 1988. Based on this agreement, energy from the Roza Power Plant is used for pumping plants within the Roza Irrigation District and energy from the plant that is not used by the pumping plants is marketed by BPA.

If the flows through the powerhouse are reduced at Chandler, the economic viability of the Chandler Power Plant may be affected. BPA makes annual investments in maintenance of the Chandler Power Plant and Reclamation is funding maintenance of the canal and facilities above the power plant. Energy from the Chandler Power Plant is marketed by BPA, but (in contrast to

the Roza Irrigation District) the Kennewick irrigation District does not receive energy directly from the plant.

4.0 Proposed New Facilities (Power Generation and Pumping Plants)

Energy generated at proposed power plants could be used to replace the energy lost due to additional subordination at the Roza and Chandler Power Plants. However this is partially offset by energy requirements at new pumping plants under the Integrated Plan. The following discussion provides a brief project description for each of the proposed plants, and general project locations are shown on Figure 2.

4.1 Hydropower Facilities

Inflow to Wymer Power Plant

A diversion at the KRD canal would connect to a new siphon near Wippel. The start of the siphon was assumed to be the head water at a new hydropower project. The new project would utilize flow into the new Wymer Reservoir. Connected to the siphon is a new 3 mile long tunnel, 12.5 feet in diameter. The tunnel discharges into the Wymer Reservoir, and the elevation of the reservoir was assumed to be the tail water. The energy for this scenario was estimated under flow conditions required to fill the Wymer Reservoir while meeting in stream flow criteria for the Yakima River.

Wymer to Roza Power Plant

This hydropower project is a new power plant near the existing Roza Dam. The project would connect to the conveyance system of tunnels and pipelines carrying flow from the Wymer Reservoir to the headworks of the Roza Canal just prior to flow being released into the Roza Canal. Energy for this scenario was estimated under flow conditions required for the Yakima River downstream of the Wymer diversion. The head water was assumed to be the Wymer Reservoir elevation, and the tail water was to be located near the discharge at the existing headworks for the Roza Canal at the Roza Dam. Head loss was based on projects of similar head, conveyance length, and conveyance diameter.

Bumping Reservoir Power Plant

Bumping Lake is located off the Yakima River approximately 30 miles south of Lake Keechelus. There is currently a plan to enlarge the reservoir with a new maximum water surface elevation of 3490 feet. A potential hydropower project utilizing the discharge from the enlarged reservoir has been considered. The head water for the project was assumed to be the water surface of the enlarged Bumping Reservoir, and the tail water elevation was assumed to be the current elevation of the existing dam outlet.

Keechelus to Kachess Pipeline Power Plant

The Keechelus to Kachess or “K to K” Pipeline is a proposed 8-foot-diameter, 5-mile-long pipeline from the Keechelus Lake to Lake Kachess. A potential hydropower project has been considered at this location. The head water at this site was assumed to be the water surface elevation at the Keechelus Lake, and the tail water was assumed to be the water surface elevation at the Lake Kachess.

Kachess Inactive Storage Tunnel Power Plant

The project at the Lake Kachess tap consists of a 12-foot-diameter conduit drawing water from Lake Kachess and discharging into the Yakima River at a new, lowered outlet structure. For the hydropower project associated with the Lake Kachess Inactive Storage Tunnel, the head water was assumed as the water surface elevation of Lake Kachess, and the tail water was assumed as the new outlet elevation. This option is an alternative to the Kachess Pumping Station.

4.2 Pumping Plants

In addition to the new generating stations, new pumping stations were included in the Integrated Plan to facilitate the use of water throughout the basin. These stations have been conceptualized in previous studies. Their project descriptions and source documents are summarized below.

Wymer Pumping Station

The Wymer Pumping Station was defined by the *Yakima River Basin Storage Study and Wymer Dam and Reservoir Appraisal Report* by Reclamation. This station would supply water to Wymer Reservoir via a new pump station on the Yakima River downstream of the reservoir.

Thorp Pumping Station

The Thorp Pumping Station is discussed in the Thorp to Wymer Conveyance Report prepared by HDR as part of the Yakima Basin Study. The Thorp Pumping Station would divert water from the Yakima River through the enlarged KRD canal to the new Wymer Reservoir.

Kachess Pumping Station

The Kachess Pumping Plant is defined in the Yakima River Basin Study Lake Kachess Inactive Storage Technical Memorandum by HDR. The intake for the project is an intake on Lake Kachess and the pump station into Kachess River. The Kachess Pumping Station is an alternative to the Kachess Inactive Storage Tunnel.

Figure 2. Pumping Plant and Energy Recovery Facility Locations

5.0 Analysis

5.1 Assumptions for Power Subordination

The following assumptions were used to determine the amount of subordination required. Relative to subordination of the Chandler Power Plant, target flows in the Yakima River at the Prosser gauging station are as follows:

- April 1 through June 30 - 1000 cfs
- June 30 through October 20 – 450 cfs
- October 20 through April 1 – 800 cfs

Relative to subordination of the Roza Power Plant, target flows in the Yakima River immediately below the Roza Diversion are as follows:

- Minimum flow – 400 cfs
- Spring flows – 1200 cfs (the exact timing of this requirement is subject to review and change depending on flow conditions in a specific year)

The instream flow requirements at the Chandler and Roza Power Plants are intended to mitigate for fish passage issues identified by the Systems Operations Advisory Committee (SOAC). The SOAC has previously identified issues with delays of the out-migration of anadromous salmonids under the current operations of the Power Plants.

Within the range of alternatives and project elements proposed in the Integrated Plan, there are a variety of features that could produce or consume power. In addition there are other existing facilities that depend on the production of power (e.g., the Roza Irrigation District pumping plants). Consideration of the current and future potential interaction of proposed project features with existing facilities and within the Integrated Plan is a complex discussion that ranges from physical logistics such as the availability / adequacy of power lines for power transmission to the contract conditions for sale and purchase of power. The purpose of this study is not to address the above concerns, but provide a preliminary estimate of annual energy produced or consumed by the various features of the project. The approach to these estimates is discussed in Section 4.3.

5.2 Water Balance Model

RiverWare is an industry standard reservoir and river mass balance model. HDR used this tool to simulate the flow and water supply benefits associated with the Yakima Basin projects. The Model inputs included a naturalized dataset derived from USGS and USBR Hydromet sources. The dataset consists of daily values from water year 1981 to 2005. The model also accounted for reservoir flow release forecasting, water supply for irrigation including canal losses, and augmentation for demand shortages not made up by other reservoirs or generated by other reservoirs failing to meet their scheduled demand releases.

For purposes of this evaluation, flows were taken from the RiverWare water balance model developed in support of the Integrated Plan.

5.3 Energy Estimate

An estimate of average annual energy was made for each proposed power generation or pumping plant facility as part of this study. The estimate was based on the gross head at each

project, typical water to wire efficiencies for hydropower facilities (includes losses and efficiencies for intakes, turbines, generators, transformers, and other electrical equipment), estimated head loss, flow from the Riverware model, and historical data from Reclamation stations. It is important to note that the timing of the flow releases was not accounted for in this estimate. This examination is a high level study intended to determine the general availability of new generating resources to offset the energy production at the Roza and Chandler Power Plants.

A number of general assumptions were made. A water to wire efficiency of 80 percent was assumed for the generating projects and 75 percent was used for the pumping projects. An estimated head loss was applied to each option based on projects of similar size and configuration. Flows through the pumping and power generation plants were taken from the Riverware water balance model developed as a part of the Integrated Plan.

The head water and tail water for the new power plants and pumping stations were briefly discussed in the project descriptions. Generally, the difference in the head and tail water elevations were considered the gross head. The head water elevation at the Wymer-Roza Power Plant was limited to el. 1730 feet, and the head water at the Bumping Power Plant was limited to el. 3490 feet. These represent the new high water elevations for these plants. The head for the new pumping stations was available from previous studies.

The Roza and Chandler Power Plant energy production numbers are based on historical information supplied by Reclamation and average flow data was not evaluated.

A summary of the estimated average annual energy can be found in Table 2.

Table 2. Estimated Energy Production

Location	Average Head (ft)	Average Flow (cfs)	Max Flow (cfs)	Average Annual MW Hours
Existing Facilities				
Roza Power Plant	158	N.A.	1077	61,000
Chandler Power Plant	118	N.A.	1470	46,000
			Total	107,000
Roza Power Plant (without April and May production)	158	N.A.	1077	47,000
Chandler Power Plant (without April, May and June production)	118	N.A.	1470	35,000
			Total	82,000
Proposed Power Plants				
Keechelus to Kachess Pipeline Power Plant	197	125	400	14,000
Kachess Inactive Storage Tunnel Power Plant[1]	135	398	1200	25,000
Wymer Reservoir Power Plant	345	102	180	21,000
Wymer-Roza Power Plant	339	174	800	34,000
Bumping Reservoir Power Plant	134	268	800	21,000
			Total	115,000
Pumping Plants				
Wymer Pumping Station[2]	475	181	1000	85,000
Thorp Pumping Station[2]	470	181	1000	84,000
Kachess Pumping Station[1]	215	427	3108	91,000

N.A. = Data not available. Power production for Roza and Chandler Power Plants were identified from Reclamation records, so flow data were not needed.

[1] The pumping station would not be needed if the Kachess Inactive Storage tunnel project is constructed.

[2] The Wymer and Thorp pump stations serve somewhat the same purpose in that both deliver water to the Wymer Reservoir and it is unlikely that they would both be built.

6.0 Results

6.1 Power Plant Estimated Capacities

To enable development of the energy estimates, a rough generating capacity for each power plant was selected based on experience with similar projects. Consideration was given to the seasonal fluctuations in head and flow, but the ultimate goal of sizing the power plant was to maximize the average annual energy production. These results are very preliminary, and upon further economic and hydrological study, the capacity, unit sizing, and number of units may more appropriately be adjusted.

Inflow to Wymer Power Plant- The head at this site fluctuates mostly between 160 and 400 feet of head. Based on preliminary turbine sizing, a Francis turbine can operate between 190

and 400 feet of head, and this operating rage was selected for the project. A sensitivity analysis indicated that limiting the head to this range has a minimal effect on generation.

The project is expected to be a single unit configuration with a capacity of approximately 4 MW. There are regular flow releases near 165 cfs, and peak flow releases of approximately 1000 cfs every 6-8 years. It is not likely to be economical for the plant to generate during these 1000 cfs releases.

Wymer - Roza Power Plant - The head at this site fluctuates significantly, but according to preliminary equipment sizing, a unit rated at 400 feet of head can operate over the entire head range.

A two unit plant was selected, with a plant capacity of approximately 21 MW. There are regular flow releases at this location at or near 165 cfs, and peak flow releases of approximately 1000 cfs annually. A small unit sized to operate efficiently at the minimum flows, and a larger unit for peak flows was initially selected for this project.

Bumping Power Plant- Two equally sized units were selected for this option with a plant capacity of approximately 5 MW. The releases vary significantly at this site. Two units were selected to accommodate a range of flow from100 to 800 cfs. The head at this site does not fluctuate significantly, and 140 feet was selected as the rated head.

Keechelus to Kachess Pipeline Power Plant- Two equally sized units were initially selected for this option resulting in a plant capacity of approximately 6 MW. At this location, there are consistent releases at 200 cfs and 400 cfs, and there is little deviation from these two flow set points, and for that reason, two identical units, each designed for 200 cfs were selected. The head at this site does not fluctuate significantly, and a rated head of 200 feet was selected.

Kachess Inactive Storage Tunnel Power Plant- A two unit configuration was selected, with a plant capacity of 13 MW. Water is generally only available at this location during the irrigation season, and there is significant variability. With two, dissimilarly sized units, most of the flow could be accommodated. The head at this site generally varies from 100 to 160 feet of head. According to preliminary equipment sizing, a turbine can operate over this range.

Table 3 shows a summary of the plant capacities, average annual energy, and construction costs for the proposed powerhouses. Although an economic evaluation was not a part of this study, a preliminary cost opinion is included in the table. The estimate was based on a unit cost of $4,600 /kW, which is consistent for small to medium sized hydropower projects and matches unit costs used to support estimates developed during the Yakima Basin Storage Study. This estimate is for the cost of the powerhouse only and does not include water conveyance costs, power transmission costs, or the probable impacts of power purchase and sale agreements.

It may be more cost-effective to purchase power to replace power generation lost due to additional subordination, rather than constructing and operating the new generation facilities discussed above. Further evaluation of the economics involved is anticipated in later stages of the Integrated Plan planning process.

Table 3. Power Plant Summary

Proposed Power Plants									
Location	Unit 1			Unit 2			Plant Capacity	Estimated Annual Energy	Estimated Capital Cost
	Head	Flow	Capacity	Head	Flow	Capacity			
	ft	cfs	MW	ft	cfs	MW	MW	MW hrs	$ Million
Wymer Reservoir Power Plant	300	165	4	NA	NA	NA	4	21,000	**16.39**
Wymer-Roza Power Plant	400	165	4	400	570	16	21	34,000	**96.60**[1]
Bumping Reservoir Power Plant	140	250	3	140	250	3	6	21,000	**27.60**
Keechelus to Kachess Pipeline Power Plant	200	200	3	200	200	3	6	14,000	**27.60**
Kachess Inactive Storage Tunnel Power Plant	140	500	5	140	775	8	13	25,000	**59.80**

[1] Assumptions used in sizing the Wymer-Roza power plant changed somewhat between development of the cost estimates used in the technical memorandum "Costs of the Integrated Water Resource Management Plan." Therefore the cost reported here is different from the cost reported in that technical memorandum ($69.2M).

6.2 Subordination Evaluation

Based on data supplied by Reclamation for power production at both the Roza and Chandler Power Plants from 1988 to 2010, which generally represents the current level of subordination, an average of approximately 107,000 MWH of energy is being produced each year. The Roza Power Plant contributes approximately 61,000 MWH to this total and the Chandler Power Plant supplies the remaining 46,000 MWH.

There have been some discussions considering the possibility of further subordination for fish passage flows by not operating the Roza and Chandler Power Plants in the spring. Specifically, the Roza Power Plant would not be used to produce power in April and May and the Chandler Power Plant would not be used to produce power in April, May and June. Based on the historical data supplied by Reclamation, this would result in an average of approximately 82,000 MWH of annual power from the Roza and Chandler Power Plants – with the Roza plant contributing 47,000 MWH and the Chandler plant contributing 35,000 MWH to that total.

A plan for further subordination has not been agreed to by the stakeholders and the estimate of power production may change based on the final duration of time frames for not operating the power plants, the ability to schedule maintenance or replacement activities (that have historically interrupted power production at other times of the year) during the selected time frames, and the need for power at the plants while they aren't producing power (i.e. the plants become a power consumer rather than a power producer).

The potential energy balance associated with multiple actions identified in the Integrated Plan was considered. All of the possible scenarios involving different combinations of the actions included in the Integrated Plan may not have yet been identified. To simplify the evaluation of potential energy production and consumption it was necessary to identify a combination of facilities associated with actions from the Integrated Plan that could be selected for implementation. This selection included generating facilities as well as pumping facilities and was constructed to attempt to include a broad range of actions from the Integrated Plan. The evaluated scenario includes energy recovery at:

- the discharge point of the Keechelus to Kachess pipeline,
- the Kachess Inactive Storage tunnel,
- the Wymer Reservoir Power Plant (inflow to Wymer originating from the Thorp Pumping Plant),
- the Wymer-Roza Power Plant (discharge from Wymer to the Roza Canal), and
- a Power Plant at the Bumping Reservoir outlet works.

The selected energy recovery facilities at Wymer Reservoir depend on water being pumped from the Yakima River at the Thorp Pump Station and therefore the energy balance must include the energy consumption of the Thorp Pumping Station. Power production and energy consumption was based on flows identified in the water balance model developed as a part of the Integrated Plan and historical energy production records for the Roza and Chandler Power Plants (1988 through 2005). In addition, further subordination of the Roza and Chandler Power Plants was considered by forgoing power production identified in the same historical records at the Roza Power Plant during the months of April and May and at the Chandler Power Plant during the months of April, May, and June. Water that normally passes through the power plants during these months would be allowed to remain in the Yakima River for fish passage issues.

Table 2 shows the energy balance that results from the above described scenario, where in stream flow criteria into the Yakima River are met in accordance with the water use model built for the integrated plan. The Thorp Pumping Station is estimated to consume 84,000 MWH of

energy annually. The Wymer Reservoir Power Plant can recover approximately 21,000 MWH and the Wymer-Roza Power Plant recovers about 34,000 MWH. There is a net loss of 29,000 MWH for the facilities associated with the Wymer Reservoir. If the Keechelus to Kachess Pipeline Power Plant, Kachess Inactive Storage Tunnel Power Plant, and the Bumping Reservoir Power Plant are all built, there would be an additional 60,000 MWH of generation available. Thus the net effect of the new power and pumping facilities under the Integrated Plan is an increase of 31,000 MWH in power production.

The current average annual energy production of the Roza and Chandler Power Plants is 107,000 MWH and the proposed additional subordination of the Roza and Chandler Power Plants would reduce the average annual energy production of these two plants to 82,000 MWH. Therefore the effect of increased subordination under the assumptions used for this analysis would be a reduction of 25,000 MWH in production at these two existing plants.

Based on these results, the overall effect of the Integrated Plan on power production would be a slight increase in power production of 6,000 MWH. Due to the considerable uncertainties involved, this is better viewed as a roughly equal balance between new power needs and new power production. It should be noted these results are based on the specific assumptions used in this analysis, and those assumptions have not been fully validated. In addition further evaluation is needed to assess the cost-effectiveness of constructing and operating new power generation facilities, versus purchasing power instead.

Table 4. Power Balance with Subordination

Estimated Average Annual Energy Production/Consumption of New Facilities		
Keechelus to Kachess Pipeline Plant	+	Produces 14,000 MWH
Kachess Inactive Storage Tunnel Power Plant	+	Produces 25,000 MWH
Wymer Reservoir Power Plant	+	Produces 21,000 MWH
Wymer-Roza Power Plant	+	Produces 34,000 MWH
Bumping Reservoir Power Plant	+	Produces 21,000 MWH
Subtotal: Energy Production of New Power Facilities	**+**	**115,000 MWH**
Thorp Pumping Station	-	Consumes 84,000 MWH
Net Energy Production of New Power and Pumping Facilities	**+**	**31,000 MWH**
Chandler and Roza Power Plant Energy Production		
Under Current Subordination Level		Produces 107,000 MWH
With Additional Subordination		Produces 82,000 MWH
Effect of Modifying Power Subordination	**-**	**25,000 MWH**
Net Effect of Integrated Plan with Additional Subordination	**+**	**6,000 MWH**

Further losses could be expected if the pumping station at Kachess is constructed instead of the Kachess Inactive Storage Tunnel Power Plant.

Additional power subordination at Chandler would not necessarily eliminate the need for flow in the Chandler canal. Because of the plant's unique configuration, changing the equipment in the powerhouse could eliminate energy generation and leave pumping capabilities for irrigation water supply in place since that capability is based on mechanically linked pumps and turbines. The mechanically linked pumps and turbines could be removed and could be replaced with electrified pumps. If this option is pursued, an analysis of the transmission requirements and energy demand would be necessary. Potential impacts to the Kennewick Irrigation District and Reclamation would also need further consideration.

There are reasonable questions about economic viability of the Roza Power Plant if flows were to be reduced further. The Roza Irrigation District will be adversely impacted if the Roza Power Plant is no longer producing power and if there are no other arrangements made to mitigate those impacts.

Approximately 800 cfs will need to flow through the Chandler Power Plant regardless of power production to run the pump-turbines and deliver water (approximately 350 cfs) to the Kennewick Irrigation District unless the pump-turbines are replaced with electric pumps and water is diverted from the river at the Chandler Power Plant. Costs and issues associated with either further subordination of the Chandler Power Plant could adversely impact the Kennewick Irrigation District. Further study will be needed to fully define the range of issues and identify potential solutions for BPA, Reclamation, and the Kennewick Irrigation District if the Chandler Power Plant is further subordinated.

7.0 Conclusions and Next Steps

To consolidate the results following the activities undertaken in this review, the following conclusions are offered:

1) The overall power balance of the Integrated Plan would be roughly neutral (no net change or a small net change) under the assumptions used in this analysis. However many of these assumptions need to be validated and may need to be modified.

2) Subordination of the Roza Power Plant, at either the current levels or at greater levels, has significant potential for financial impact on the Roza Irrigation District.

3) Subordination the Chandler Power Plant, at either the current levels or at greater levels, presents the potential for significant issues associated with maintenance and operation of the plant for continued delivery of irrigation water that could impact the Kennewick Irrigation District.

4) If new power plants or pumping stations are constructed, each facility would require a new agreement with BPA for either power purchase or sale.

5) New transmission lines or upgrades for existing transmission lines may be required. Work will be required to assess those requirements and estimate the cost of any needed transmission improvements. Under the Yakima Basin study no estimates have been developed for the cost of transmission capacity. If transmission facilities for any of the power production facilities prove to be prohibitively expensive, the power balance shown in this memorandum will need to be adjusted.

6) There are many interdependencies among these facilities that will complicate their operation (e.g. energy recovery at the terminus portal of the tunnel from the Kittitas Reclamation District above Wymer Reservoir inherently requires operation of the Thorp Pump station).

7) The cost effectiveness and optimum configuration of the new plants and the coordination of the timing of diversions and power production were beyond the scope of this study and will require further evaluation.

8)The full range of implications associated with increasing the level of subordination has not been fully explored at this time because a preferred project configuration has not been identified. Further consideration subordination should include a more complete evaluation of impacts and potential benefits in coordination with the Integrated Plan and actions to be implemented.

8.0 List of Preparers

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