Appendix F4
Option Characterization - Importation

Appendix F4 — Option Characterization – Importation

1.0 Introduction

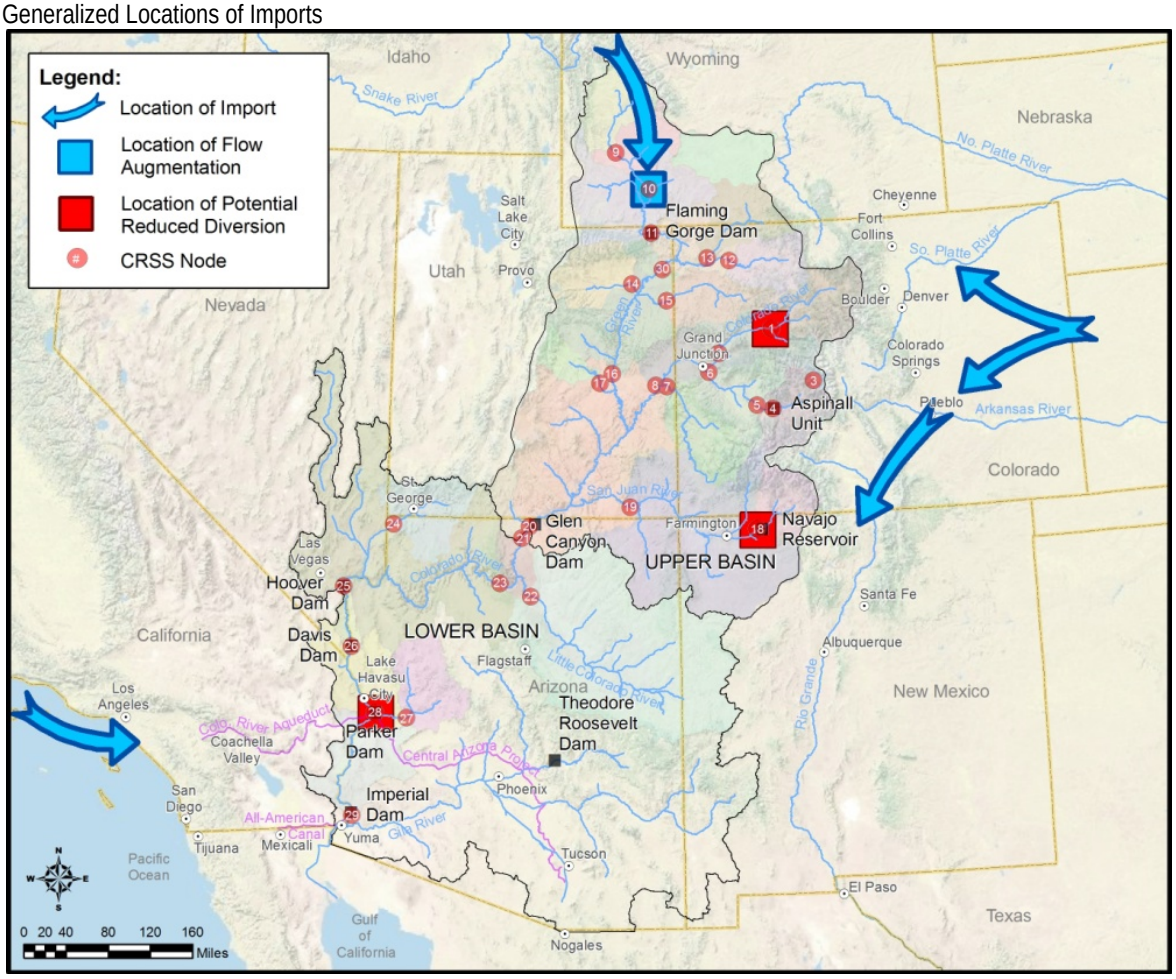
River and other out-of-basin freshwater imports have been proposed to increase the overall water supply of the Colorado River Basin (Basin). Fourteen options related to river or other freshwater imports were submitted for consideration in the Colorado River Basin Water Supply and Demand Study (Study) and are available electronically on the compact disc accompanying this report and on the Bureau of Reclamation's (Reclamation) Study website at http://www.usbr.gov/lc/region/programs/crbstudy.html.

The submitted options were reviewed and organized into groups according to the location at which the imported water would augment the Colorado River or provide exchange water for regions reliant on Colorado River supplies. The submitted options were reviewed and organized into three groups according to the source of imported water:

- Imports to the Colorado Front Range
- Imports to the Green River
- Imports to Southern California

The general location of these options are shown in figure F4-1, with the arrow indicating the flow of imported water and the red square indicating the points of reduced Colorado River diversion. Representative options were developed for each option group to represent the distinct nature of the options.

FIGURE F4-1
Generalized Locations of Imports



This appendix summarizes the types of options received, the assumptions made, and methods used to characterize the options, and the characterization results. A detailed description of the characterization criteria, approach, and rating guidance is provided in the appendix F3.

2.0 Imports to the Front Range

This group of options includes importing water from the Missouri River or Mississippi River to areas adjacent to the Basin that could use this water to meet projected shortfalls and/or reduce the amount of water these areas divert from the Basin. All of the Import to Front Range options involve large-scale diversion facilities (at least 800 cubic feet per second intake and diversion facilities), more than 700 miles of conveyance infrastructure spanning at least two states, and more than 700 megawatts (MW) of power for pumping. Water would be conveyed to the Front Range of Colorado and to specific areas of New Mexico and integrated into existing water supply systems. Although these options are termed “imports,” water would not actually be imported into the Basin. Rather, water would be delivered to system reservoirs serving these adjacent areas to reduce the amount of water exported from the upper Colorado and San Juan rivers.

Two representative options were developed from this group of options to reflect the differences in potential location of diversion, conveyance infrastructure needs, and associated impacts. The representative options are:

- Missouri River Imports
- Mississippi River Imports

Imports to the Front Range will reduce additional demand for Colorado River water beyond current transbasin facility yields, presumably eliminating or reducing the development of new transbasin facilities.

2.1 Missouri River Imports

Yield for the Missouri River concept was limited by the realistic hydraulic capacity of a single large-diameter pipeline. Specifically, limiting the pipe diameter to 144 inches and maintaining flow rates so that friction loss is less than 1 foot per thousand feet of pipe length results in a yield of about 600,000 acre-feet per year (afy). Because the available diversion from the Missouri River is not envisioned to be supply-limited to 600,000 afy, multiple parallel pipes could increase the quantity of yield of this option.

The Missouri River option is a very large-scale infrastructure project, requiring more than 700 miles of conveyance infrastructure crossing two states and more than 700 MW of power for pumping. Although the conveyance distance is longer than similar historical projects (Central Arizona Project, Colorado River Aqueduct, California State Water Project), it does use the type of infrastructure that has proven to be highly reliable. Therefore, confirming technical feasibility should not take more than 5 years. However, the permitting phase will require multi-state negotiations, possible permits for new power plants, and an Environmental Impact Statement as required by the National Environmental Policy Act. Even if the permit process were pursued with urgency and with political support, the process is expected to take up to 15 years. Once permitted, numerous design and construction crews could be mobilized to simultaneously construct several segments of the project. Therefore, it is possible to construct large-scale water transmission projects of this size in approximately 10 years. In summary, the following timeframe is estimated: feasibility is 5 years, permitting is 15 years, and implementation is estimated at 10 years, totaling 30 years.

To estimate the cost, topographic and aerial mapping was used to select a rough alignment for the proposed conveyance corridor. The pumping needs were estimated based on evaluating topographic relief and maintaining industry-standard pressures. Once the size of the pipeline and number and size of the pumping stations were determined, cost database information was used to estimate the total capital costs. The database estimates include adjustments to estimated costs by considering the proposed location of the project and the scale of the project. As such, both location and economies of scale were considered in the capital cost estimates. Total capital costs were estimated to be approximately $8.6 billion. Annual costs include electricity costs for 12,000 kilowatt hours per acre-feet (af), maintenance, repair, and replacement costs. Electricity costs assume that a project of this size would get favorable electricity rates due to the large and consistent energy demand. Specifically, a cost of $0.07 per kilowatt hour was assumed to cover all aspects of the energy rate. This cost is consistent with current electricity costs in the corridor (Black Hills Energy, 2012). The annual costs for maintenance, repair, and replacement are based on a percentage

of the capital costs from a compiled database of information of historical costs for these items on similar facilities. Considering all of the above, an estimated unit annual cost of $1,700 per af was estimated.

In addition to yield, timing, and cost, the Missouri River importation concept was characterized against several other criteria. This importation option was estimated to have very high energy needs and high potential for permitting, legal, and policy challenges because of the project's size, geographic extent, and concerns related to potential impacts in the source watersheds. The resulting ratings for these criteria are low. The Missouri River option would have high debt service costs because it is a capital-intensive project. Therefore, the option did not score well against the operational flexibility criteria because the high cost of debt would still be incurred if the project is put into an idle mode. Imports from the Missouri River would alleviate or reduce the need to develop additional infrastructure to divert additional water beyond current infrastructure yields from the Colorado River headwaters. Compared to increased Colorado headwater diversions, this options may improve Colorado River Basin hydropower, water quality, recreation, and may improve some in-basin environmental conditions. However, it is worth noting that it is possible that the option could introduce some adverse impacts on the same criteria in the basin of origin as a result of reduced flows in the Missouri River. Imports to the Front Range would result in water quality that would meet all drinking water standards with conventional water treatment, but the source water quality would be poorer than the current supply used by many Front Range urban purveyors. Agreement from the State of Colorado, and the many water providers within Colorado, would have to occur in order for this option to occur. Moreover, to the extent that this option would require the reduction of the amount of water that the state of Colorado is legally entitled to take from the Basin, this option could require an amendment to the Colorado River Compact of 1922 (Compact) and Upper Colorado River Basin Compact of 1948.

2.2 Mississippi River Imports

This concept is similar to the Missouri River option, but the diversion location is significantly farther downstream along the Mississippi River system. Specifically, the proposed diversion location is near Memphis, Tennessee, downstream of the confluence of the Ohio River and Mississippi River. By extending the concept to this location, the flows at the diversion location are significantly higher, and because the diversion location is much closer to the Gulf of Mexico, the potential impacts to downstream users are reduced. However, extending the concept to this location requires an additional 340 miles of conveyance facilities and 200 MW in pumping needs (increasing the estimated capital costs to $14.6 billion). With that background, the assumed yield of this option is identical to the Missouri River option, at 600,000 afy. The estimated unit annual cost is higher, at $2,400 per af. Although a larger project, the Mississippi River option is assumed to require the same amount of time to implement—30 years. This option was characterized the same as the Missouri River option on all other characterization criteria. Agreement from the State of Colorado, and the many water providers within Colorado, would have to occur in order for this option to occur. Moreover, to the extent that this option would require the reduction of the amount of water that entities within Colorado would take from the Basin to which they are legally entitled to take, this option would require an amendment to the Colorado River Compact and Upper Colorado River Basin Compact.

3.0 Imports to the Green River Headwaters

This group of options includes diverting water from the upper headwaters of rivers adjacent to the Green River to the headwaters of the Green River. Potential sources of supply are diversions from the Bear River, upper Snake River[1], or Yellowstone River. These potential projects involve intake and diversion facilities, pumping plants and conveyance facilities, and delivery to the Green River. Because these options are focused on headwaters-to-headwaters transbasin diversions, the size of the projects (in terms of magnitude of water and facilities required) are smaller in scale than other importation options. With the Green River headwaters concepts, the availability of divertible supply is the primary limiting factor, as defined in previous analyses prepared as part of the Colorado River Augmentation Study (Colorado River Water Consultants, 2008).

Three representative options were developed from this group of options to reflect the differences in potential location of diversion, conveyance infrastructure needs, and associated impacts. The representative options are:

- Bear River Imports
- Snake River Imports
- Yellowstone River Imports

3.1 Bear River Imports

Specific to the Bear River concept, the proposed diversion location is directly downstream of Smith's Fork near Cokeville, Wyoming. It is worth noting that approximately 175 miles downstream of this location, the fresh water flows into the Great Salt Lake and is lost. Based on a series of relatively high-level hydrologic assessments (Colorado River Water Consultants, 2008), a yield of 50,000 afy was estimated as potentially feasible near Smith's Fork. For perspective, the Bear River at this location has historically had annual flow volumes of between 800,000 af and 100,000 af, with an average annual flow of about 300,000 af.

The facilities required for the Bear River option include a new river diversion, a new reservoir, 12 miles of pipe, 2.5 miles of tunnel, and two pumping stations. This type of infrastructure has been proven to be reliable. Therefore, project feasibility could potentially be evaluated within a few years. Although the required infrastructure is technically proven, the conveyance facilities cross areas designated as state or national forests. Therefore, special use permits for construction in the public lands will be required. Also, transbasin water projects have become increasingly challenging to permit because of both political and environmental concerns. Therefore, at least 7 years of permitting is anticipated. Once permitted, numerous design and construction crews could implement these types of projects in up to 5 years. In summary, the following timeframe is estimated: feasibility is 3 years, permitting is approximately 7 years, and implementation is approximately 5 years, totaling 15 years.

[1] Among the more than 150 options submitted to Reclamation as responsive to the *Plan of Study*, additional importation of water supplies from various sources, including importation of water from the Snake and Columbia River systems, were submitted to the Study. Such options were appropriately reflected in the Study but did not undergo additional analysis as part of a regional or river basin plan or any plan for a specific Federal water resource project. This Study is not a regional or river basin plan or proposal or plan for any Federal water resource project.

Costs for this concept were developed by roughly sizing all of the required infrastructure components and then using an engineering cost estimating tool to roughly quantity the cost for each of the sized infrastructure components. Considering the total estimated capital cost, as well as the cost for interest, energy costs for pumping, and costs for all other required annual operations, maintenance, repair and replacement resulted in an estimated unit annual cost of $720 per af. In addition to yield, timing, and cost, the Bear River option was characterized against several other criteria. Key considerations related to technical feasibility, permitting, legal, and policy were largely covered in the descriptions above related to estimating option timing. The option scored low on long-term viability criteria because of its combination of risk from energy inflation and risk of future policy decisions that could limit diversions from the basin of origin. The option rates relatively poorly on operational flexibility owing to high debt service costs that would still exist when the option is put into an idle mode. The options would result in more water imported into the headwaters and therefore is anticipated to improve Basin hydropower, water quality, recreation, and may improve some in-basin environmental conditions. However, there are also potential adverse impacts to the Bear River basin due to reduced flows. Without extensive and detailed study, it is not possible to ascertain if the benefits to the Basin would be greater than or less than the adverse impacts to the basin of origin. At this time, neutral overall impacts are assumed for recreation and hydropower. Because the diversion would reduce Bear River flows through the Great Salt Lake Delta and the Bear River Migratory Bird Refuge, this option was characterized slightly lower than similar Green River Imports options.

3.2 Snake River Imports

According to the Snake River Interstate Compact (Snake River Compact, 1949), Wyoming has rights to deplete 4 percent of the annual flow in the Snake River at the state line. The first 2 percent of that water can be directly diverted, but diversions of more than 2 percent require storage along the river to assist in the management of potential impacts to Wyoming diversions. For this reason, 33,000 af of storage along the Snake River in the Palisades Reservoir has been allocated to Wyoming. This option investigates using Wyoming rights to divert 33,000 afy from the Snake River during high-flow periods and store that water in Palisades Reservoir. Then the water would be pumped through 26 miles of pipe and 6 miles of tunnel into the headwaters of the Green River Basin. The estimated yield for this option is 33,000 afy.

In regards to timing, Wyoming has the water rights to divert and use this water. However, because the proposed water use is related to a transbasin diversion, approval by the State of Idaho is required by Article 4 of the Snake River Compact. Therefore, it is assumed that this option could not be implemented any faster than the Bear River option. Specifically, 3 years of feasibility, 7 years of permitting and interstate negotiations, and 5 years of construction, totaling 15 years, would be required.

In regards to costs, this option would require approximately $200 million in new pumping and conveyance facilities, and when factoring in energy costs and all other required annual operations and maintenance costs, the resulting unit annual cost is estimated to be about $800 per af.

Compared to the Bear River importation option, the Snake River option received slightly better ratings for permitting and other environmental factors because a new reservoir is not required for this option. However, the Snake River option received a slightly lower rating on legal criteria attributable to potential complexities related to agreements with Idaho and the Snake River Compact.

3.3 Yellowstone River Imports

Wyoming is allocated 60 percent of the depletable yield of the Clark's Fork of the Yellowstone River. According to the 1973 Wyoming Framework Water Plan (Wyoming State Engineer's Office, 1973), Wyoming's 60 percent allocation is 428,000 af in an average year. Currently, very little water is depleted from this river basin. However, it is also worth noting that this river has been designated wild and scenic, which could affect the ability to obtain diversion permits. The proposed option is for 75,000 afy (or 20 percent of Wyoming's depletable allocation). The option includes diverting water from Clark's Fork near the Wyoming state line and conveying the water approximately 45 miles to the Buffalo Bill Reservoir, where pumps, pipes, and tunnels would be used to convey the water an additional 90 miles to the Green River Basin.

In regards to timing, the proposed technology is well-proven, and a technical feasibility study could be completed in less than 3 years. However, the permitting and negotiations with the downstream state (Montana) would likely take at least 7 years. If permitted, the projects could be constructed over a 5-year duration.

In regards to cost, this option includes a considerably longer alignment than the other imports to the headwaters of the Green River options, and the cost is reflective of the longer length with an estimated unit annual cost of $1,900 per af. For the same reason, the energy needs of this option are slightly higher than other Green River imports options.

In regards to other characterization criteria, this option was characterized almost identically to the Snake River imports options because of the general similarities of the options.

4.0 Imports to Southern California

This group of options is focused on importing high-quality water from other regions using ocean routes to Southern California coastal areas. Potential sources of water include the Columbia[2] River, rivers in Alaska, or icebergs. Delivery mechanisms include sub-ocean pipelines for Columbia River supplies, tanker ships for Alaskan river supplies, or tug boats for icebergs. All of the options in this group require extensive transport or conveyance of water from the source regions to Southern California and require relatively complex facilities and operations to integrate the supply within the current water supply system in Southern California.

[2] Among the more than 150 options submitted to Reclamation as responsive to the *Plan of Study*, additional importation of water supplies from various sources, including importation of water from the Snake and Columbia River systems, were submitted to the Study. Such options were appropriately reflected in the Study but did not undergo additional analysis as part of a regional or river basin plan or any plan for a specific Federal water resource project. This Study is not a regional or river basin plan or proposal or plan for any Federal water resource project.

Four representative options were developed from this group of options to reflect the differences in potential location of imported water, modes of transport and conveyance, and associated impacts. The representative options are:

- Columbia River Imports
- Icebergs
- Tankers
- Water Bags

4.1 Columbia River Imports

This concept includes constructing a diversion structure near the mouth of the Columbia River, which would feed a sub-ocean pipeline that would travel along the coast to Southern California before turning inland to deliver water to the local Southern California water infrastructure system. The availability of supply for locations such as the mouth of the Columbia River was not estimated to be the limiting factor. For this group of options, the limiting factor is based on the capacity and configuration of existing infrastructure in Southern California. Integrating large quantities of new supply to offset Colorado River diversions would be difficult due to infrastructure constraints. Although the exact integration limit is difficult to quantify, 600,000 afy was estimated based on rough estimates of integration capability. This volume is coincidentally consistent with other large-scale import options and therefore provides some degree of comparability to other import options.

The time required to implement this type of option is highly uncertain. This is because sub-ocean pipelines of the proposed size and length are largely unprecedented. Therefore, the feasibility phase is assumed to take at least 10 years and may require some pilot testing of sub-ocean pipeline designs. The permitting phase may also take 10 years to conduct interstate negotiations and the need to complete an environmental impact statement. Finally, construction of more than 1,000 miles of 144-inch sub-ocean pipeline across large submarine canyons could take up to 20 years. All combined, the timing for this option is assumed to be 40 years.

The cost of this option is also highly uncertain. The costs available on this option are dated and are presented on a dollar-per-af basis without sufficient explanation as to how the unit cost was calculated (Reclamation, 1971). By updating past Reclamation costs from 1971 estimates and making adjustments for considering a smaller-scale concept than the one considered in 1971, this option is roughly estimated to have a unit annual cost of at least $3,400 per af.

In addition to timing and cost, this option did not rate for any of the other characterization criteria except water quality due to difficult feasibility, permitting challenges, and unknown environmental impacts. Only water quality was rated higher due to the importation of better water quality from the Columbia River than the existing Colorado River supply.

4.2 Imports via Icebergs

This concept includes wrapping large water bags around icebergs in the Alaska region and using tug boats to transport the frozen water to a port along the coast of Southern California. As the water melts in the water bags, the water would then be pumped to a transfer station at the port and then pumped and piped to locations such as Diamond Valley Lake for treatment

and consumption. A small iceberg contains 250 to 850 af. Assuming approximately one iceberg transported per day, this would yield approximately 200,000 afy.

In regards to timing, this option would require the construction of a new terminal similar to the design of an oil-receiving terminal at a sea port. Next, pipes and pumps would need to be permitted from the port to the targeted receiving lake (assumed to be Diamond Valley Lake). Based on these considerations, this option is assumed to take at least 10 years for feasibility, 5 years in permitting, and 5 years in construction, totaling at least 20 years. Because this type of project would most likely be completed in phases, additional phases are assumed to require another 10 years to complete.

In regards to cost, assumed costs to lease very large tug boats were developed through research of existing industry practices. These include the cost of the boat, crew, and fuel. The cost to construct a new terminal at an existing port near Los Angeles was estimated based on recent studies to build a new oil terminal in Los Angeles (Los Angeles Economic Development Corporation, 2008). The cost to build pipelines and pump stations from the port to Diamond Valley Lake were based on the cost of previously completed pipelines and pumping stations in this region. The resulting capital costs were estimated to be approximately $3.5 billion. Based on all of these considerations, the estimated unit annual costs are $2,700 per af.

In regards to other characterization criteria, this option requires significant amounts of fuel and therefore the rating for energy needs is low. Also, the rating for long-term viability is low because of the risk that escalating fuel prices could further increase the cost of this option.

4.3 Imports via Tankers

The tanker option is very similar to the iceberg option. Large tanker ships would be used to accept water in a port near a river in Alaska and deliver the water to the same type of port in Southern California that was described in the iceberg option. Large tankers could have capacities of 276 to 445 af (Ocean Shipping Consultants, 2007). Maximum annual yield of 600,000 af is again assumed to be limited by the existing distribution system. The same integration infrastructure is required from the Southern California port to a lake such as Diamond Valley Lake. Owing to the need for larger ships and a second port in the exporting basin, the costs may be slightly higher than the iceberg concept. However, developing and utilizing water bags would not be required. A rough estimate of the unit annual cost of this option is $2,900 per af. In regards to yield, timing, and all other characterization criteria, the option characterizes exactly the same as towing icebergs. Characterization of this option was performed as increments of 200,000 afy in order to capture issues of scale and other complexities of large-scale programs.

4.4 Imports via Water Bags

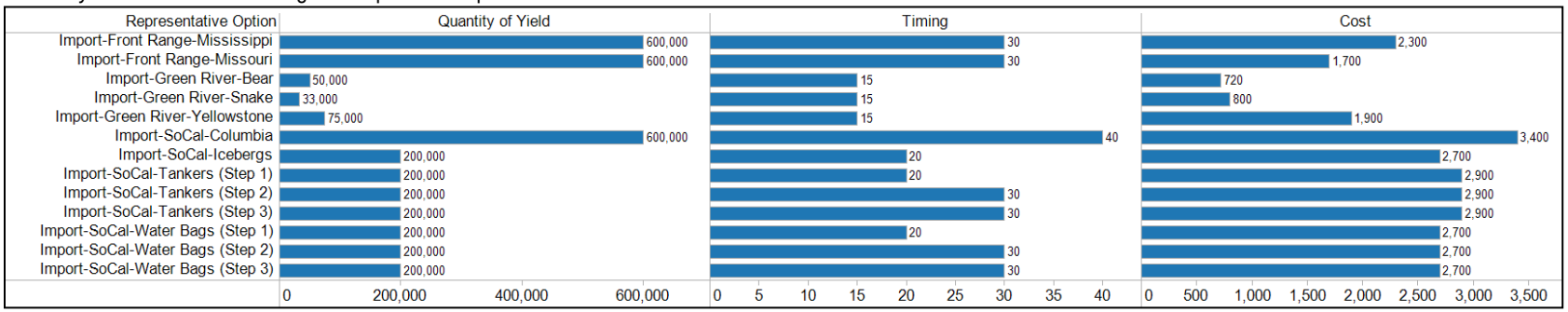
This option is exactly the same as the tankers option, but except instead of using tankers, the option focuses on capturing fresh water near the mouth of several large rivers in Alaska. Water bags are expected to have capacities of about 40 af. This option is assumed to characterize exactly the same as tankers.

5.0 Characterization Results

A summary of the characterization findings are shown in table F4-1. The top portion of the table shows the estimated quantity of yield, earliest timing of implementation, and estimated cost. The bottom portion of the table shows the 17 criteria and associated ratings ("A" through "E") and is color-scaled. In general, "C" is typically designated as mostly neutral; "A" is largely positive; and "E" is largely negative. Refer to appendix F3 for specific criteria descriptions and rating scales.

Notes providing detailed justification for each option criteria rating are available in electronic form on the accompanying compact disc and on Reclamation's website at http://www.usbr.gov/lc/region/programs/crbstudy.html.

TABLE F4-1
Summary Characterization Ratings for Importation Options



Criteria

Representative Option	Quantity of Yield	Timing	Cost	Technical Feasibility	Implementation Risk	Long-Term Viability	Operational Flexibility	Permitting	Energy Needs	Energy Source	Other Environmental	Recreation	Socioeconomics	Policy	Legal	Hydropower	Water Quality
Import-Front Range-Mississippi	A	D	D	B	C	C	D	D	E	C	C	A	C	D	D	A	C
Import-Front Range-Missouri	A	D	C	B	C	C	D	D	E	C	C	A	C	D	D	A	C
Import-Green River-Bear	E	C	B	A	A	D	D	D	C	C	D	C	C	C	D	C	C
Import-Green River-Snake	E	C	B	A	A	D	D	B	D	C	C	C	C	C	E	C	C
Import-Green River-Yellowstone	E	C	C	A	A	D	D	B	E	C	C	C	C	C	D	C	C
Import-SoCal-Columbia	A	E	E	E	D	E	D	E	E	C	D	C	C	E	E	D	B
Import-SoCal-Icebergs	D	C	D	D	D	D	D	C	E	D	C	C	C	D	C	C	A
Import-SoCal-Tankers (Step 1)	D	C	D	D	D	D	D	C	E	D	C	C	C	D	C	C	A
Import-SoCal-Tankers (Step 2)	D	D	D	D	D	D	D	C	E	D	D	C	C	D	C	D	A
Import-SoCal-Tankers (Step 3)	D	D	D	D	D	D	D	C	E	D	D	D	C	D	C	D	A
Import-SoCal-Water Bags (Step 1)	D	C	D	D	D	D	D	C	E	D	C	C	C	D	C	C	A
Import-SoCal-Water Bags (Step 2)	D	D	D	D	D	D	D	C	E	D	D	C	C	D	C	D	A
Import-SoCal-Water Bags (Step 3)	D	D	D	D	D	D	D	C	E	D	D	D	C	D	C	D	A

6.0 References

Black Hills Energy Corporation. 2012. *Schedule of Rates for Electrical Service, Large Industrial Customer, Transmission Rate Class*.

Bureau of Reclamation (Reclamation). 1971. *Study Work Plan for California Undersea Aqueduct, Reconnaissance Investigation, Working Document*. September.

Colorado River Water Consultants. 2008. *Study of Long-Term Augmentation Options for the Water Supply of the Colorado River System*.

Los Angeles Economic Development Corporation. 2008. *Crude Oil Marine Terminal at the Port of Los Angeles Economic Impact Study*.

Ocean Shipping Consultants, 2007. *The Tanker Market, Mixed Outlook Ahead*

Snake River Compact. 1949. Available at: http://waterplan.state.wy.us/BAG/snake/briefbook/ss_compact.htmlref

Wyoming State Engineer's Office. 1973. *The Wyoming Framework Water Plan*. May.