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Susitna Hydroelectric Project

Project Evaluation

Interim Memorandum

FINAL

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Executive Summary

A hydroelectric project on the Susitna River has been studied for more than 50 years and is again being considered by the State of Alaska as a long term source of energy. In the 1980s, the project was studied extensively and a license application was submitted to the Federal Energy Regulatory Commission (FERC). The project was cancelled in 1986 due to a variety of reasons. In 2008, the Alaska State Legislature authorized the Alaska Energy Authority (AEA) to perform an update of the project. That authorization also included an Integrated Resource Plan (IRP) to be performed by others to evaluate the ability of this project and other sources of energy to meet the long term energy demand for the Railbelt region of Alaska. Hydroelectric power is of particular interest to the IRP because it provides stable electricity rates due to renewable river flow, rather than the fluctuating rates of fossil fuel-generated electricity.

HDR was contracted by AEA to update the 1980s cost estimate, energy estimate, and schedule and to evaluate the economics of the project. This report summarizes the results of that study. Based largely on the 1986 FERC license application, the following project development alternatives have been reviewed and updated.

- **Watana.** This alternative consists of the construction of a large storage reservoir on the Susitna River at a site named Watana, with an 885-foot-high rock filled dam, and a powerhouse containing 6 turbines with a total installed capacity of 1,200 megawatts (MW).
- **Low Watana.** This alternative consists of the Watana dam constructed to a lower height of 700 feet, along with a powerhouse containing 4 turbines, with a total installed capacity of 600 MW.
- **Watana/Devil Canyon.** This alternative consists of the full-height Watana development, plus a second reservoir located downstream at a site called Devil Canyon. This downstream reservoir would re-regulate river flow and be impounded by a 646-foot-high concrete dam. The Devil Canyon powerhouse would have an installed capacity of 680 MW. After the FERC license is issued, these 2 dams and powerhouses would be constructed sequentially without delays. The combined Watana/Devil Canyon developments would have an installed capacity of 1,880 MW.
- **Staged Watana/Devil Canyon** *(low height Watana, plus Devil Canyon, plus full-height Watana)***.** This alternative would ultimately result in the same configuration as the previous alternative, but the Watana dam would be initially constructed to the lower height and the Watana powerhouse would only have 4 out of the 6 lower-head turbine generators installed. The Watana construction crew would demobilize and move downstream to construct the Devil Canyon dam and powerhouse, then either demobilize again, delay further construction, or return upstream to complete the Watana dam to its full height and install the remaining 2 units. The staged capacity of Watana would increase from 600 MW to 1,200 MW for a total project capacity of 1,880 MW.
- **Devil Canyon.** This alternative consists of the Devil Canyon dam, without Watana dam, with a Devil Canyon powerhouse containing 4 turbines, with a total installed capacity of 680 MW. Note that Devil Canyon was intended to be a regulating dam, paired with the

Watana reservoir. Without the larger upstream Watana reservoir, the Devil Canyon alternative would have minimal storage for providing power in winter.

Energy for each of the project alternatives was estimated. Susitna project hydrology, along with reservoir, waterway, and turbine-generator performance data were developed. Model inputs including daily flow for the period of record, reservoir capacity curves, spillway capacity, and tailwater curves were updated, based largely on the 1980's studies, license application, and amendment.

Cost estimates for each alternative were updated. These updates were based on the original 1983 FERC application, including its preliminary design, quantities and associated cost estimate, with several modifications from a 1986 license amendment. For the water-to-wire turbine-generator equipment cost estimates, budget pricing was requested directly from manufacturers. A contingency of 20 percent of direct construction costs was set, which is typical for preliminary design. Project licensing, environmental studies, engineering design and construction management, were estimated at 11 percent of direct construction costs. Cost estimates were developed using conservative assumptions and further review of existing infrastructure and industry practices may reduce costs.

The project schedule was updated to reflect changes in federal and state regulations, including several significant environmental legislation acts and modifications to the FERC licensing process. Based on the modern Integrated Licensing Process (ILP), obtaining the FERC license for Susitna is expected to require an ambitious sustained effort, with issuance of the license expected in approximately 8 years. The licensing process would involve extensive public outreach, stakeholder involvement, and coordination of fishery, botanical, wildlife, cultural resource, and other supporting studies. This approach would by necessity be much more comprehensive than the license process in the 1980's. To expedite the overall schedule to bring the project on line, environmental field studies and engineering design would be developed in parallel with the license application.

Preliminary economic analyses were also developed for each project alternative to determine the average cost of electricity per kilowatt hour. These economic analyses were based on the updated estimates of cost, energy, and schedule for each of the project alternatives, thereby identifying the economically preferred alternative. For this preliminary analysis, the following major assumptions were used to compare each alternative:

1. No inflation
2. 100 percent financing with no capital contribution by the State
3. Bond interest rate is 5 percent with a term of 50 years
4. All energy will be sold
5. Debt coverage ratio of 1.25
6. Ongoing O&M and capital expenditures costs and schedule as estimated in Section 3.3 of this report.

These assumptions provide the basis for a relative comparison between the alternatives.

The results of this study are summarized in Table 1. The Watana/Devil Canyon alternative is the most cost effective per unit of energy. The Devil Canyon alternative does not provide a stable winter energy supply although its cost per kWh is lower than the other alternatives.

Table 1 Summary

Alternative	Ultimate Capacity (MW)	Construction Cost ($billion)	Energy (billion kWh/yr)	Schedule (years)	Cost per kWh ($)	
					First 50 Years	Second 50 Years
Watana	1,200	8.4	3.1	15 – 16	0.22	0.01
Low Watana	600	6.9	2.4	14 - 15	0.20	0.01
Watana/Devil Canyon	1,880	11.7	7.2	15 - 20	0.14	0.01
Staged Watana/Devil Canyon	1,880	12.8	7.2	14 - 23	0.18	0.01
Devil Canyon	680	5.0	2.9	14-15	0.13	0.02

Hydroelectric power has many economic and environmental benefits including long-term rate stabilization. Because the cost of the water to power a hydroelectric turbine is essentially free the cost per kilowatt hour is related to the construction and maintenance costs of the dam and powerhouse facilities. As we have seen recently, the price of fossil fuels can fluctuate dramatically over time whereas the cost of hydroelectric power decreases once the initial investment has been repaid and remains low and stable for the life of the project. Consequently the economic risk associated with hydroelectric power is substantially lower than thermal power. Additionally, the life cycle carbon dioxide production of hydroelectric facilities is orders of magnitude less than thermal power plants.

1 Background

The Susitna River has its headwaters in the mountains of the Alaska Range about 90 miles south of Fairbanks. It flows generally southwards for 250 miles before discharging into Cook Inlet just west of Anchorage. Contained entirely within the south central Railbelt region, the Susitna River is situated between the two largest Alaska population centers of Anchorage and Fairbanks.

The Bureau of Reclamation first studied the Susitna River's hydroelectric potential in the early 1950s, with a subsequent review by Corps of Engineers in the 1970s. In 1980, the Alaska Power Authority (APA; now the Alaska Energy Authority) commissioned a comprehensive analysis to determine whether hydroelectric development on the Susitna River was viable. Based on those studies, the APA submitted a license application to the Federal Energy Regulatory Commission (FERC) in 1983 for the Watana/Devil Canyon project on the Susitna River. The license application was amended in 1985 for the construction of the Staged Watana/Devil Canyon project at an estimated cost of $5.9 billion (1985 dollars).

Developing a workable financing plan proved difficult for a project of this scale. When this existing difficulty was combined with the relatively low cost of gas-fired electricity in the Railbelt, the declining price of oil throughout the 1980s, and its resulting impacts upon the State budget, the Power Authority's Board of Directors terminated the project in March 1986.

At that point, the State of Alaska had appropriated approximately $227 million to the project from FY79-FY86, of which the project had expended $145 million to fund extensive field work, biological studies, and activities to support the FERC license application. Though the Power Authority concluded that project impacts were manageable, the license application was withdrawn and the project data and reports were archived to be available for reconsideration sometime in the future.

In 2008, the Alaska State Legislature, in the FY 2009 capital budget, authorized the AEA to reevaluate the Susitna Hydro Project. The authorization also included a Railbelt Integrated Resource Plan (IRP), which will evaluate various sources of electrical power to satisfy the long term energy needs for the Railbelt portion of Alaska. To date the IRP has not yet been completed.

The Susitna and other hydroelectric projects are of particular interest to the AEA and the State because hydroelectric power, unlike gas-fired electricity, is not tied to the fluctuating price of fuel, and can provide long-term rate stability, which in turn allows for long-term growth planning.

1.1 Project Scope

The scope of this new study was to collect and review pertinent information from the original studies and license application from the 1980's. Using this past work as a basis, this reevaluation estimated project energy and projects costs; developed a project schedule; and, using this information, evaluated in 2008 dollars the economics for the development alternatives generally described in the 1983 FERC license application.

Both the initial FERC license application and this reevaluation analyzed several project alternatives:

- **Watana.** This alternative consists of the construction of a large storage reservoir on the Susitna River at a site named Watana, with a new rock filled dam 885-foot-high, with a powerhouse containing 6 turbines, with a total installed capacity of 1,200 megawatts (MW).
- **Low Watana.** This alternative consists of the Watana dam constructed to a lower height of 700 feet, along with a powerhouse containing 4 turbines, with a total installed capacity of 600 MW.
- **Watana/Devil Canyon.** This alternative consists of the full-height Watana development, plus a second reservoir located downstream to re-regulate river flow, impounded by a new 646-foot-high concrete dam, at a site named Devil Canyon. The Devil Canyon powerhouse would have an installed capacity of 680 MW. After the FERC license is issued, these 2 dams and powerhouses would be constructed sequentially without delays. The combined Watana/Devil Canyon developments would have an installed capacity of 1,880 MW.
- **Staged Watana/Devil Canyon** *(low height Watana, plus Devil Canyon, plus full-height Watana)***.** This alternative would be the same as the previous alternative, but the Watana dam would be initially constructed to the lower height and the Watana powerhouse would only have 4 out of the 6 lower-head turbine generators installed. The Watana construction crew would demobilize and move downstream to construct the Devil Canyon dam and powerhouse, then either demobilize again, delay further construction, or return upstream to complete the Watana dam to its full height and install the remaining 2 units. The staged capacity of Watana would increase from 600 MW to 1,200 MW for a total project capacity of 1,880 MW.
- **Devil Canyon.** This alternative consists of the Devil Canyon dam, without Watana dam, with a Devil Canyon powerhouse containing 4 turbines, with a total installed capacity of 680 MW. Note that Devil Canyon was intended to be a regulating dam, paired with the Watana reservoir. Without the larger upstream Watana reservoir, the Devil Canyon alternative would have minimal storage for providing power in winter.

A total of 7 alternatives were evaluated. Only the 5 alternatives listed above are presented in this report. A Watana alternative with 6 turbines and a Devil Canyon alternative with 6 turbines were evaluated and found to have higher construction and capital costs with only a minimal increase in energy thus resulting in higher energy costs when compared to the same alternatives with 4 turbines. Thus the 6 turbine options for these alternatives were eliminated from further consideration.

Preliminary energy, cost, and schedule estimates for the 5 analyzed alternatives are described in Sections 2 through Section 4, economic evaluation in Section 5, and regulatory and environmental issues in Section 6.

2 Preliminary Energy Estimate

2.1 Hydrologic Analysis

To develop an updated energy estimate for the Susitna hydroelectric project the existing hydrologic record was updated. At the time the original study was issued in 1983 the hydrologic record contained data from 1950 to 1981. The project team recreated that record from synthesized gage record hydrology for the Watana/Devil Canyon dam sites, transposed from raw daily flow data from United States Geological Survey (USGS) gauge 1529000 at Gold Creek using a straight drainage area proration, and found correlation between the new record and the annual average flow from the original study. Based on this hydrology, a full record was developed for the period from 1950 to 2007. The hydrology of the upper Susitna Basin is dominated by melt water from snow and glaciers in the spring and summer, and substantial freezing during the winter months. As a result, a majority of the flow occurs between mid-April and mid-October.

A review of current literature indicates a lack of consensus on the manner in which precipitation and runoff might be affected by the impacts of either natural variability and/or potential man-made global climate changes. For this report we assume that future hydrologic conditions will be similar to those of our recent past experience.

2.2 Energy Model Analysis

Energy for each of the project alternatives was estimated using Computer Hydro-Electric Operations and Planning Software (CHEOPS), a proprietary energy modeling software. Hydrology was updated in conjunction with project civil, mechanical, and electrical performance data. In addition to daily flow, model inputs included: reservoir capacity and area curves, based on the 1985 FERC amendment; tailwater curves; spillway capacity, with minimum and maximum operation; and evaporation coefficients, all based on the 1985 FERC amendment. Total reservoir evaporation was estimated between 1 and 3 inches per month in summer, with negligible evaporation during the winter when frozen.

Equipment performance was based on manufacturer data obtained in 2008 specifically for this project. Average generic turbine performance curves were then developed for the model, peaking at 95 percent range of efficiency and 92 percent at full gate. Generator performance curves were also developed, peaking at 98 percent. The six 200-MW Watana turbines were rated at a design head of 680 feet and a minimum operating head of 545 feet. The four 170-MW Devil Canyon turbines were rated at 600 feet and a minimum operating head of 450 feet.

For the Watana/Devil Canyon alternative, the target elevations from the 1985 FERC amendment were used to simulate reservoir operation. In that paired configuration, the Devil Canyon power plant provides the base load while the Watana plant is used for peaking power. Alternative scenarios were also run for the Low Watana and Watana operating without Devil Canyon. In these cases, the target elevations for the Watana reservoir were designated to maximize for winter generation. For the Low Watana alternative, four turbine generators would be installed; each rated at about 150 MW. Other key assumptions for the model included:

- Environmental flow constraints from 1985 as a baseline, despite the fact that new environmental regulations may change requirements on minimum flow and ramping rates
- Energy demand will be sufficient to consume all the energy produced by the project
- A forced outage factor of 1.5 percent for both Devil Canyon and Watana
- Transformer losses of 2 percent of the total generation
- Sedimentation should not have a significant impact on reservoir operation, though 1985 studies indicated 12 percent of the dead storage in the Watana Reservoir will be lost due to sedimentation after 100 years of operation, and no sedimentation rates have been included in the present model
- Firm energy is based on the low water year of the 57-year hydrologic record

The resulting preliminary energy estimates are presented in Figure 2.1 and Figure 2.2 and summarized in Table 2.1. Detailed input and results of these energy analyses are provided in Appendix A.

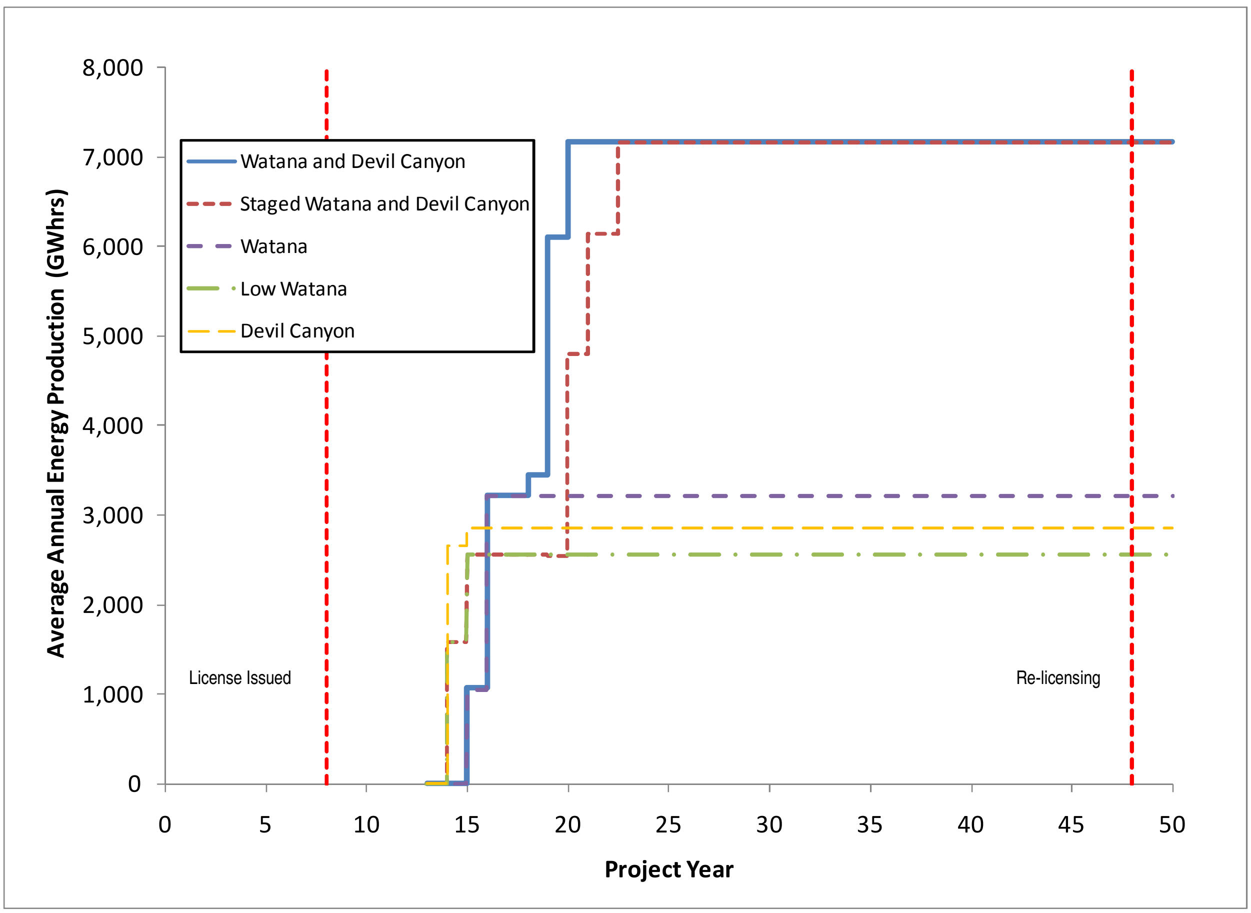


Figure 2.1 Energy Estimates for Susitna Project Alternatives

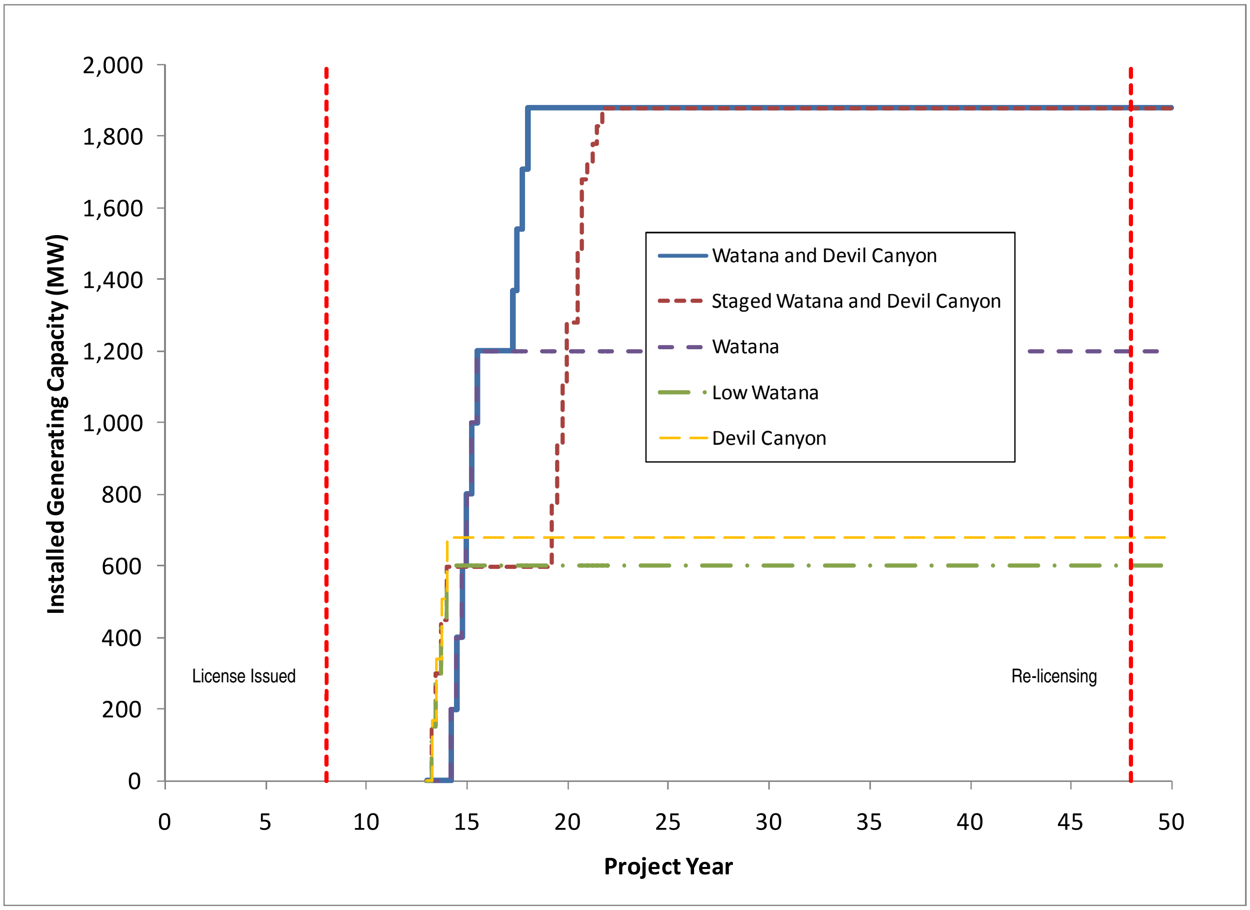
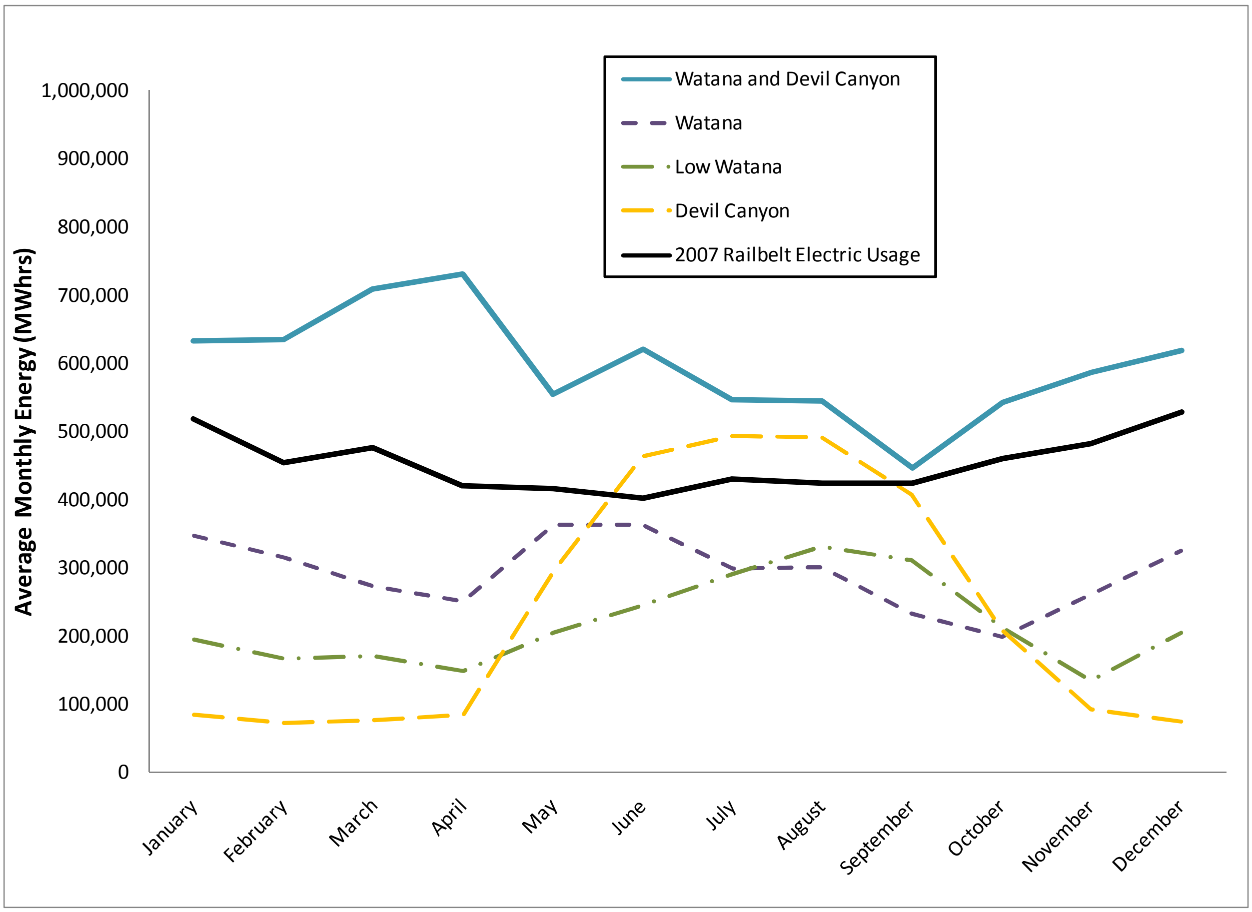


Figure 2.2 Capacity for Susitna Project Alternatives

Table 2.1 Preliminary Energy Estimate		
Alternative	**Estimated Average Annual Energy (Billion kWh/year)**	**Estimated Firm Energy* (Billion kWh/year)**
Watana	3.2	1.8
Low Watana	2.6	1.4
Watana/Devil Canyon	7.2	4.1
Staged Watana/Devil Canyon	7.2	4.1
Devil Canyon	2.9	2.3

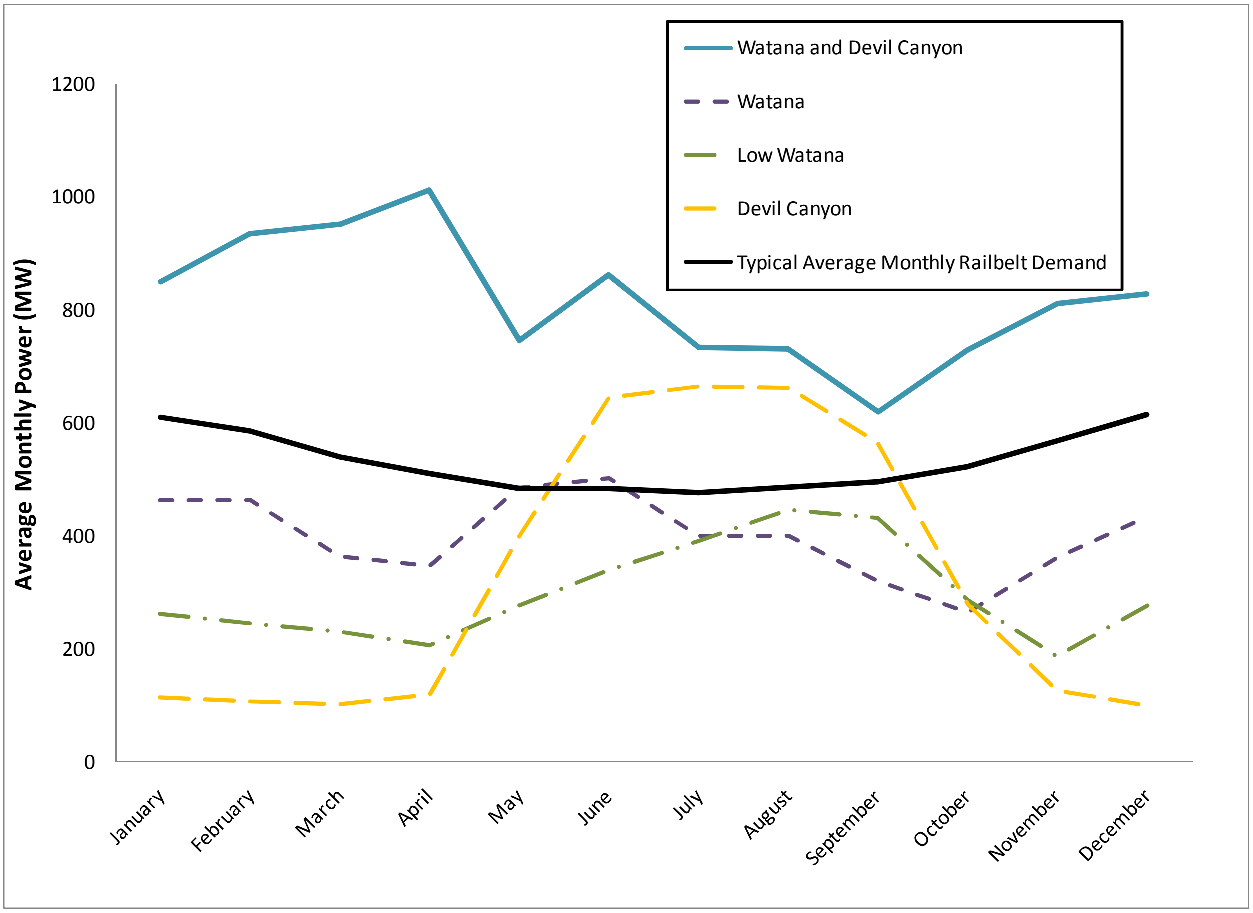
*Firm energy is based on the low water year of the 57-year hydrologic record

The energy production for the project alternatives will be influenced by seasonal flow variations. The Susitna development was originally designed as a cascade system to store energy for use during the winter. The Watana reservoir provides storage capacity and peaking power with the Devil Canyon powerhouse providing base load power. This allows for water to be stored in the Watana reservoir during the spring and summer floods and run through the Devil Canyon powerhouse during the winter months. As can be seen in Figure 2.3 and Figure 2.4, the Devil Canyon reservoir alone does not provide enough storage capacity to allow for substantial energy to be generated during the winter months.



*Railbelt electricity usage obtained from the U.S. Department of Energy

Figure 2.3 Seasonal Energy for Susitna Alternatives with Rule Curve to Maximize Winter Generation



*Railbelt electricity demand obtained from the U.S. Department of Energy, 2007

Figure 2.4 Seasonal Capacities of Susitna Alternatives with Rule Curve to Maximize Winter Generation

3 Preliminary Cost Estimate

3.1 Original Cost Estimate

To develop an updated cost estimate for the Susitna hydroelectric project as conceptualized in the 1980s, project documents from that era, including project descriptions, drawings, and cost estimates were researched. A detailed cost estimate, prepared in the original feasibility study in 1982, was located. The estimate for the Watana/Devil Canyon alternative totaled $5.0 billion (in 1982 dollars). Also located was a 1986 study estimate for the staged Watana/Devil Canyon alternative at $5.5 billion (1986 dollars). These 2 original estimates were compared and found to be very similar, except for the intervening escalation and a few line-item differences; for example, an environmental mitigation line item was included in the 1986 cost estimate as part of licensing, but this item was not listed the 1982 estimate. Other changes from 1982 to 1986 included an increase in contingency from 17.5 percent to 20 percent and an increase in engineering from 12.5 percent to 15 percent.

3.2 Updated Cost Estimate

2008 cost estimates for each alternative were created based on quantities from the original 1982 estimate with a few modifications from the 1986 estimate. U.S. Cost, a company specializing in cost estimates for large projects, developed the unit prices for 2008. Cost estimates were developed using conservative assumptions; further review of existing infrastructure and industry practices may reduce costs.

For the water-to-wire turbine-generator equipment estimates, budget pricing was requested directly from manufacturers. The water-to-wire equipment includes: turbines, generators, turbine shutoff valves, and other miscellaneous mechanical/electrical equipment, and installation. A data sheet of head, flow, and power ratings was prepared for the 10 potential turbine-generators at Watana and Devils Canyon. The invitation was sent to Alstom, VA-Tech, Voith Siemens, and Toshiba; and pricing, performance, delivery, dimensions, and weights were requested. Of these, 3 budgetary offers were received, evaluated, and incorporated into the 2008 estimate. Transformer prices were also quoted from ABB.

A contingency of 20 percent of direct construction costs was used, which is typical for preliminary design. Use of this contingency was judged acceptable due to the advanced stage of the engineering studies performed in the 1980s. Project licensing, environmental studies, engineering design, and construction management were estimated at 11 percent of direct construction costs including contingency. A figure of 12 percent is typical, though due to economy of scale, the percentage has been adjusted slightly, pending more detailed design and service estimates in the future.

The unit prices in this report are typical for large projects in the United States. Variations in cost will likely be covered within the 20 percent contingency used in this estimate. The 2 largest line item construction costs are the gravel fill for the Watana dam and the concrete for the Devil Canyon. If the unit prices for these items were undervalued by as much as 25 percent each, the effect on the total construction costs would only be 2 percent. The approach used for this report was to apply the unit prices consistently to the various alternatives. This approach allows a common platform from which to establish priority among the alternatives. Although future refinement of the estimated unit costs may affect the final economics of the project it should not affect the ranking of the alternatives amongst themselves.

The resulting preliminary construction cost estimate is shown in Table 3.1. Detailed construction cost estimates are provided in Appendix B.

In addition to construction costs, the project will incur other costs such as financing costs and interest before construction is complete. These costs are assumed to be rolled into the long term bonds that will be issued for each alternative. The sum of construction costs and financing costs, plus other related costs that are included in the debt service, are the capital costs of the project. The capital costs shown in Table 3.1 reflect the total debt that would be issued for each alternative.

Table 3.1 Preliminary Cost Estimate

Alternative	Estimated Construction Cost (billions)	Estimated Capital Cost (billions)
Watana	$8.4	$10.5
Low Watana	$6.9	$8.3
Watana/Devil Canyon	$11.7	$14.5
Staged Watana/Devil Canyon	$12.8	$15.9
Devil Canyon	$5.0	$6.0

3.3 Operations and Maintenance Cost Estimate

The economic analysis for this project will require estimates of operations and maintenance costs (O&M) and capital expenditures. The annual costs for these items are based on the following assumptions:

- Annual operation and maintenance for the power facilities is estimated at $10 million per year for each of the alternatives. This annual cost is based on other hydroelectric projects of comparable size and location. For the roads and other infrastructure, it is assumed that once the construction is completed, a portion of the maintenance would be subsidized by the project, equating to approximately $5 million per year and is the same for each of the alternatives.
- Capital expenditures will occur on the following schedule:

- Every 20 years, the turbine runners will require replacement due to cavitation. The replacement cost is estimated at approximately $5 million per turbine.
- Every 20 years, the governors will require upgrades. The replacement cost is estimated at approximately $0.5 million per turbine.
- Every 40 years, the generator rotor and stator will require rewinding. This work is estimated at approximately $10 million per turbine.
- Every 40 years, the transformers will require rehabilitation. This work is estimated at approximately $0.4 million per transformer. Watana has 9 transformers and Devil Canyon has 12, plus one spare transformer for each dam.
- Every 50 years, the spillways will require structural repairs. A total of $12.5 million is assumed for each dam or $25 for the two-dam alternatives.
- Every 50 years, the transmission lines will require rehabilitation. A total of $10 million is assumed for each project alternative.
- Every 50 years, the dam structures will require rehabilitation. A total of $25 million is assumed for each dam, or $50 million for two dams.
- The project FERC license will expire after 50 years from issuance. Five years before this expiration, a relicensing effort will begin, and both environmental and regulatory work will be required. A total of $100 million is assumed spread evenly over this 5 year period.

4 Preliminary Project Schedule

An updated schedule was developed for each of the project alternatives. These schedules extend from approval, through licensing, design, construction, and commissioning. The primary purpose of this schedule is to provide a timeline for estimated cost cash flow and estimated energy revenue to determine economic feasibility. This schedule assumes that:

- Construction times are estimated based on 1982 FERC license application.
- The licensing process from start to FERC order is estimated at 7 to 10 or more years. We have set a reasonable target of 8 years for the proposed project analysis, provided that the effort is begun immediately, ambitiously, fully funded, and conducted in parallel with environmental studies, engineering, and with active public outreach and cooperation by stakeholders.
- The FERC License Application will be based on the 1986 application, updated to reflect more than 20 years of regulatory changes and modern engineering and construction methods.
- Any environmental studies will be based on 1980 and 1986 studies, updated to reflect present site conditions, public interests, wildlife, and recreational needs.
- Construction will begin immediately upon issuance of the license.
- Roads and staging will be state permitted outside the FERC project and will begin several years before FERC license, including pioneer and permanent roads, airports, bridges, construction camps, staging areas, and towns. Building roads in this way is the quickest way to meet the projected timeline although there is some uncertainty whether permits could be obtained to construct these facilities before the project license is issued.
- Construction of diversion dams and tunnels will begin on issuance of the license, with upstream and downstream coffer dams and tunnels to divert the Susitna River during construction of main dams at Watana/Devil Canyon.
- Spillway construction will follow diversion dam and tunnel construction, and will include site preparation, approach channels, control structures, gates, stoplogs, chute, and flip buckets for main and emergency spillways.
- The full-height dam construction at Watana will require an 885-foot-high rock-fill dam following site preparation, grouting, and installation of a pressure relief system.
- The main dam construction at Devil Canyon will include a thin-arch concrete dam, preceded by site preparation, foundations, abutments, and thrust blocks. Rock-fill saddle dam construction will follow grouting and pressure relief system.
- The powerhouse and transmission will include power intake, tunnels/penstock, surge chamber, tailrace, powerhouse, turbine/generators, mechanical/electrical systems, switchyard, control buildings, and transmission lines.
- Reservoir filling will be based on the latest hydrologic data for inflow and turbine data for outflow.

- Devil Canyon construction will commence immediately upon completion of Watana for the Watana/Devil Canyon alternatives.

The resulting estimate of generation of first power and full power is shown in Table 4.1. Detailed schedules for all of the alternatives are provided in Appendix C.

Table 4.1 Power Generation Time Estimates

Alternative	Generation of first power (years)*	Generation of full power (years)*
Watana	15	16
Low Watana	14	15
Watana/Devil Canyon	15	20
Staged Watana/Devil Canyon	14	23
Devil Canyon	14	15

*From start of licensing

5 Economic Analysis

An economic analysis was developed for each of the project alternatives. This analysis used the energy, cost, and schedule information prepared in previous tasks to determine the cost of electricity per kilowatt hour (kWh) for each of the project alternatives, thereby identifying the economically preferred alternative.

For this preliminary analysis, the following major assumptions were used to compare each alternative:

7. No inflation
8. 100 percent financing with no capital contribution by the State
9. Bond interest rate is 5 percent with a term of 50 years
10. All energy will be sold
11. Debt coverage ratio of 1.25
12. Ongoing O&M and capital expenditures costs and schedule as estimated in Section 3.3 of this report.

These assumptions provide the basis for a relative comparison between the alternatives. AEA proposed the first 4 assumptions and the fifth assumption regarding debt coverage ratio is the same ratio as used in the 1980s studies. These assumptions will be modified as the study progresses so that the Susitna alternatives will be evaluated on the same basis as other power generation alternatives in the IRP.

The financial markets are currently under a great deal of stress and it is unlikely that bonds could be sold today under the assumptions noted above. However, it is anticipated that the bond market will be functioning normally at the time when substantial capital inputs are required for construction. Future analyses should consider potential financing mechanisms, such as those related to carbon markets or offset investments under a cap-and-trade program as proposed by the Obama-Biden Administration.

The assumption of no capital contribution by the State requires that construction financing or bridge loans are available until construction is complete and power generation begins. The bridge loan is assumed to roll over each year and convert into long-term debt at the beginning of the first full year of operation. The interest rate on the bridge loan is assumed to be 5 percent annually. Debt payments are assumed to start in the first full year of operation.

It is unlikely that the AEA-proposed 100 percent financing with no capital contribution by the State or another party could be achieved. The licensing and construction period for a major hydroelectric facility is very long and even if construction financing were available for these activities the lenders would in all likelihood require at least interest payments until electric generation started. Since the project would not have an income stream until generation starts, the State or another entity would be liable for the interest payments. An assumption of no capital contributions or grants by the State of Alaska or the federal government results in a high cost of energy for a Susitna hydroelectric project. Grants from these entities could substantially reduce the cost of energy during the period when debt is being repaid.

A debt coverage ratio (DCR) of 1.25 requires that the net operating income be 1.25 times greater than the annual debt payments. A 1.25 ratio was used in the 1985 Susitna report and it is assumed that this ratio could be negotiated with the bond underwriters in the future. The surplus revenues generated by this DCR are placed in a reserve fund and the fund increases each year with accrued interest and an annual contribution from the DCR until such time as the reserve fund in year X plus the net income in year X+1 are large enough to pay off all the remaining debt. Thus the reserve fund decreases the length of time when debt payments are required.

As noted in Section 3.3 of this report, capital expenditures will be required during the life of the project following completion of construction activity for such activities as replacing turbine runners, rewinding generators, FERC relicensing, etc. These costs are assumed to be paid from a reserve fund that accrues modest amounts of surplus cash sufficient to cover the ongoing capital expenditures through the first 100 years of the project. The spreadsheet model seeks the minimum cost of energy that is sufficient to meet these capital expenditures and operations and maintenance costs. It is anticipated that through proper design and operations of the project there will be minimal loss of energy, if any, while these repair and replacement activities are ongoing. The analysis assumes no change in annual power generation for plant maintenance or repair and replacement.

Figure 5.1 shows the cost of electricity for each of the project alternatives from year 1 through year 100. The Watana-only alternatives average about $0.24 per kWh of electricity for the bond payment time interval, falling to about $0.01 per kWh after debt service is eliminated. The Low Watana alternative debt service is paid off sooner than the Watana alternative so the average cost of electricity for the first 50 years is lower for the Low Watana alternative.

The Watana/Devil Canyon alternative or the Staged Watana/Devil Canyon alternative result in higher costs for electricity than the other alternatives in the first few years of generation since much larger capital costs are incurred and there is limited power generation in the first few years compared to the capital expenditures. The DCR magnifies this peak electricity cost since net operating revenues must be 1.25 times the annual debt service and these alternatives are slowly increasing their generating capacity. A similar cost increase was identified in the 1980s studies.

When full generating capacity is achieved for the Watana/Devil Canyon alternative or the Staged Watana/Devil Canyon alternative, the cost of electricity is substantially lower than for the Watana-only alternatives at about $0.15 to $0.16 per kWh (Figure 5.1). However, for the Staged Watana/Devil Canyon alternative, the substantially-higher cost of energy during the first years of generation results in the average cost per kWh during the first 50 years being about $0.18 per kWh (Table 5.1). The Watana/Devil Canyon alternative has an average cost of electricity of about $0.14 per kWh for the first 50 years. Energy costs drop to slightly more than $0.01 per kWh for both of the multiple dam alternatives after the bonds are paid off.

The Devil Canyon alternative has a cost of power that is slightly lower ($0.13 per kWh) than the Watana/Devil Canyon alternative during the first 50 years and slightly higher cost of power after the debt is paid. As noted earlier in this report the Devil Canyon alternative has limited winter generation capacity, although the cost of energy is lower than the other alternatives.

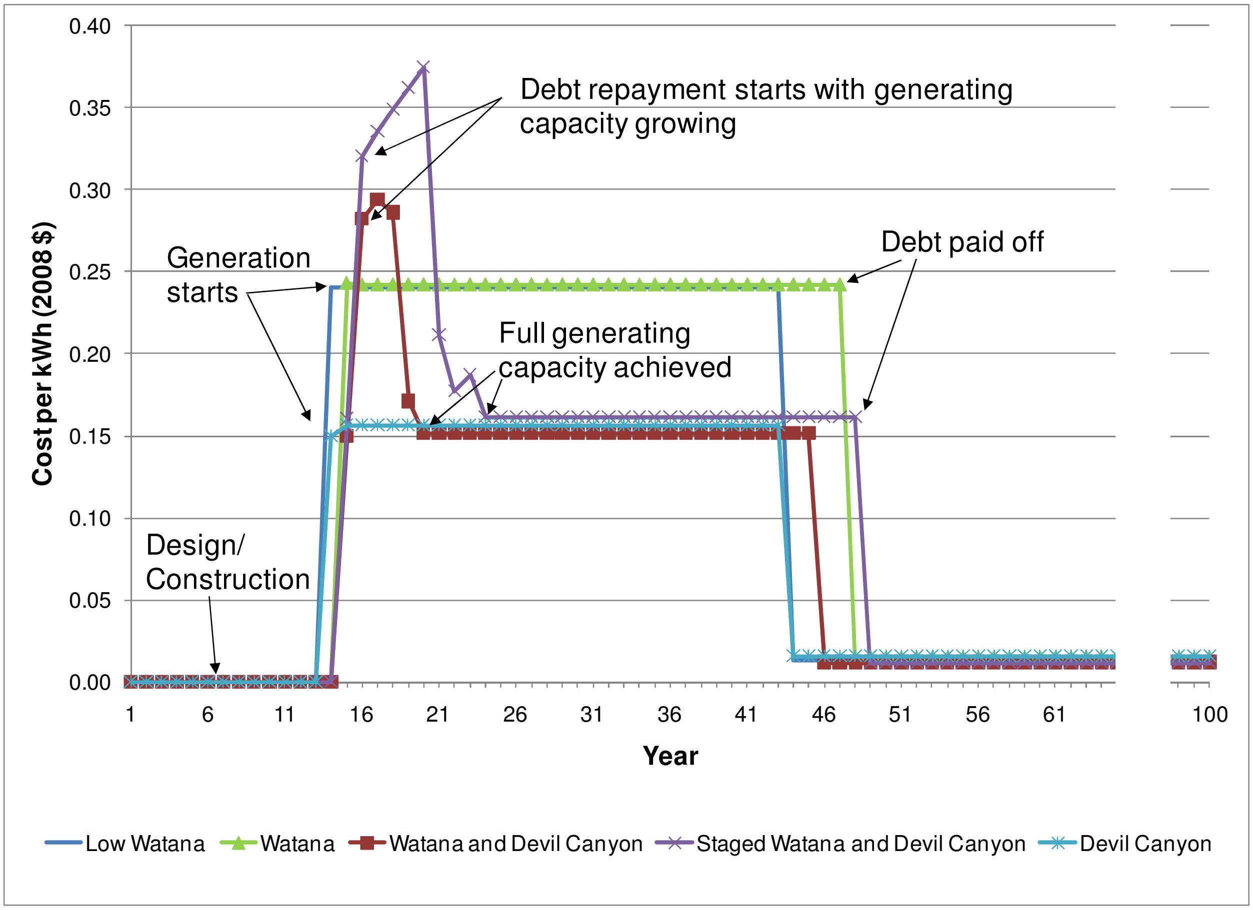


Figure 5.1 Cost of Electricity per Kilowatt Hour for Susitna Hydroelectric Alternatives

Based on the average cost of electricity during the first 50 years of the project and the second 50 years (Table 5.1), the Watana/Devil Canyon alternative or the Devil Canyon alternative would be preferred over the other alternatives, with the Watana/Devil Canyon alternative having slightly lower costs after the debt service period. If winter electricity is an objective of this project then the Watana/Devil Canyon alternative is preferable to the other alternatives. The average cost of electricity during the first 50 years is calculated as the average cost, starting with the first year of generation, and continuing through year 50. The average includes some years when the cost of electricity is very low following payment of the debt.

Table 5.1 Average Cost of Electricity Per Kilowatt Hour		
Alternative	**Cost Per Kilowatt Hour (2008 dollars)**	
	First 50 Years	**Second 50 Years**
Watana	$0.22	$0.01
Low Watana	$0.20	$0.01
Watana/Devil Canyon	$0.14	$0.01
Staged Watana/Devil Canyon	$0.18	$0.01
Devil Canyon	$0.13	$0.02

A sensitivity analysis was performed to estimate the effect of varying interest rates on the cost of power. Table 5.2 shows the average cost per kWh during the first 50 years for each alternative. A reduction in the interest rate from 5 percent to 3.5 percent results in a decrease of 3 cents to 5 cents per kWh depending on the alterative. However, an increase in the interest rate to 6.5 results in increases of six to nine cents per kWh.

Table 5.2 Average Cost of Electricity Per Kilowatt Hour at Varying Interest Rates			
Alternative	**Cost Per Kilowatt Hour, First 50 Years (2008 dollars)**		
	3.5%	**5%**	**6.5%**
Watana	$0.17	$0.22	$0.31
Low Watana	$0.15	$0.20	$0.28
Watana/Devil Canyon	$0.11	$0.14	$0.20
Staged Watana/Devil Canyon	$0.14	$0.18	$0.25
Devil Canyon	$0.10	$0.13	$0.18

Figure 5.2 through Figure 5.11 provide additional detail on each of the 5 alternatives that were evaluated. There are 2 graphs presented for each alternative. The first graph displays the cost per kilowatt hour for the first 100 years of the project and the second graph displays the construction cost expenditures in each year and the total cost of debt in any year. The vertical scales are the

same across all 5 alternatives (i.e., $0 to $0.40 per kWh for cost of electricity and $0 to $16 billion for construction expenditures and total debt) so that the relative difference between alternatives is more apparent.

The Devil Canyon alternative has the lowest total debt structure of the 5 alternatives, followed by the Low Watana alternative and then the Watana alternative. The Watana/Devil Canyon alternative has a lower total debt structure than the Staged Watana/Devil Canyon alternative because the construction period is shorter and the total capital costs are lower.

Table outputs for the models and a discussion of the model parameters are provided in Appendix D.

5.1 Watana

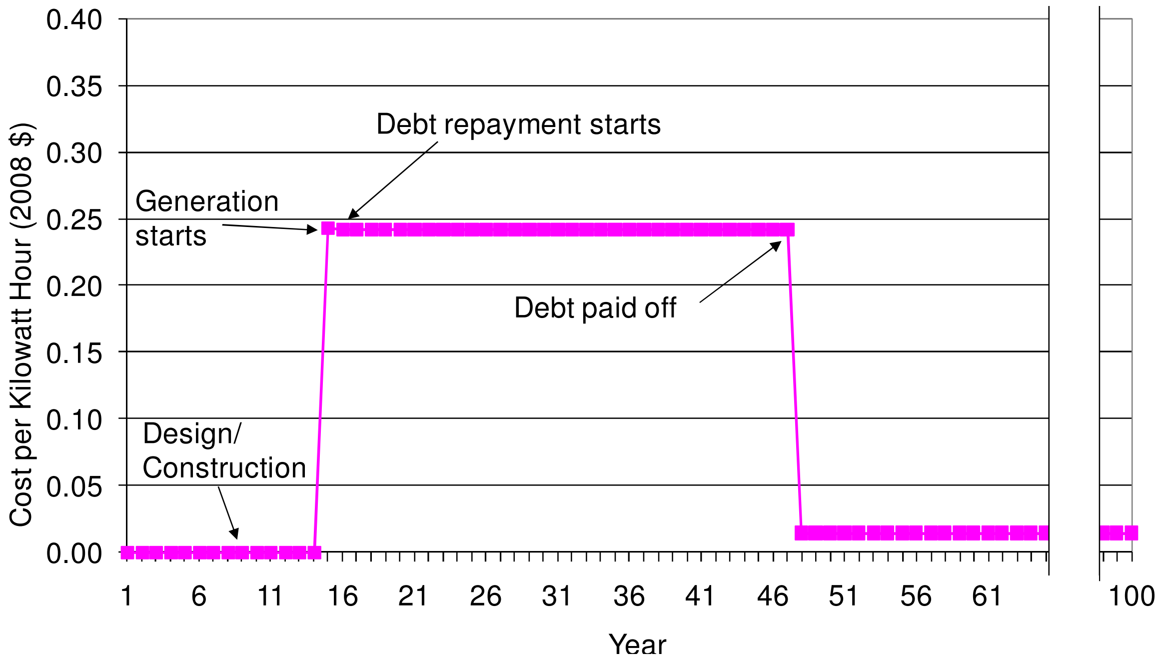


Figure 5.2 Watana Cost of Electricity

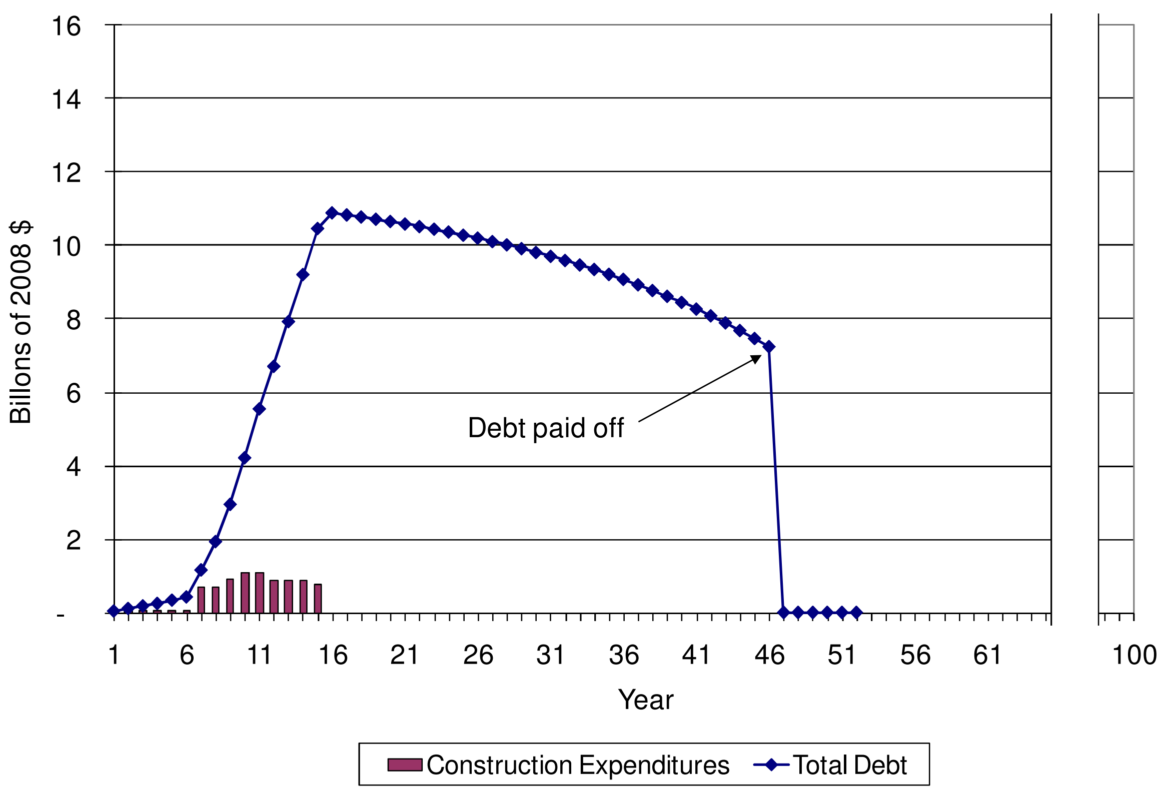


Figure 5.3 Watana Annual Construction Expenditures and Total Debt

5.2 Low Watana

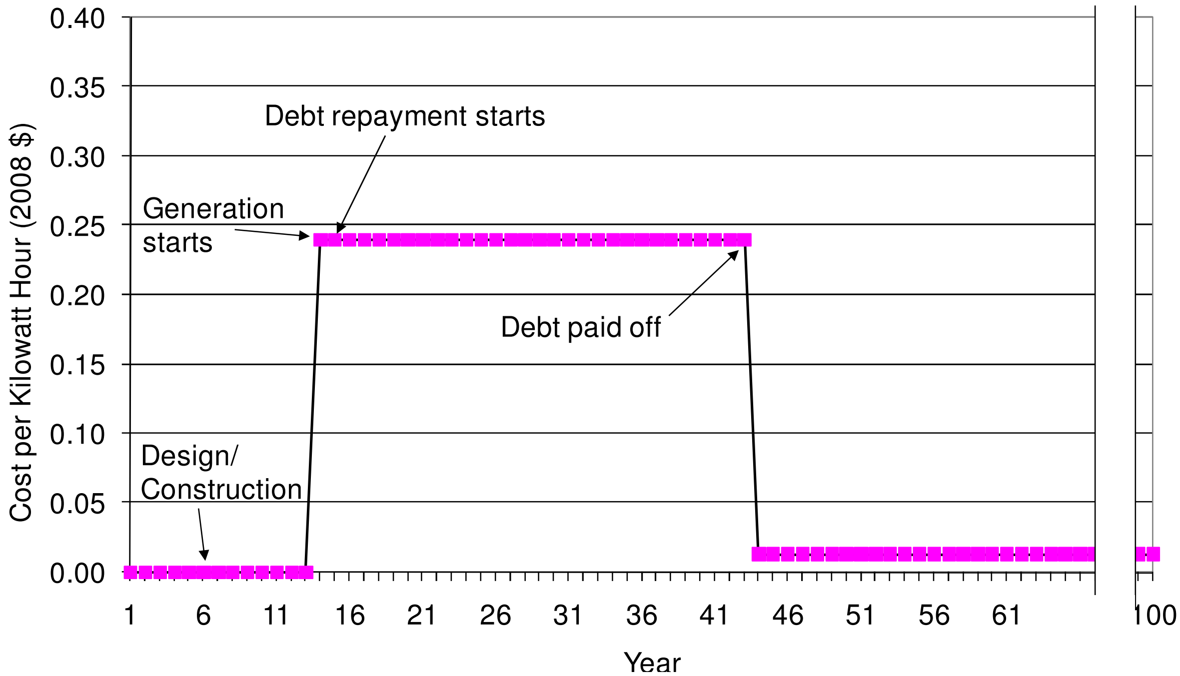


Figure 5.4 Low Watana Cost of Electricity

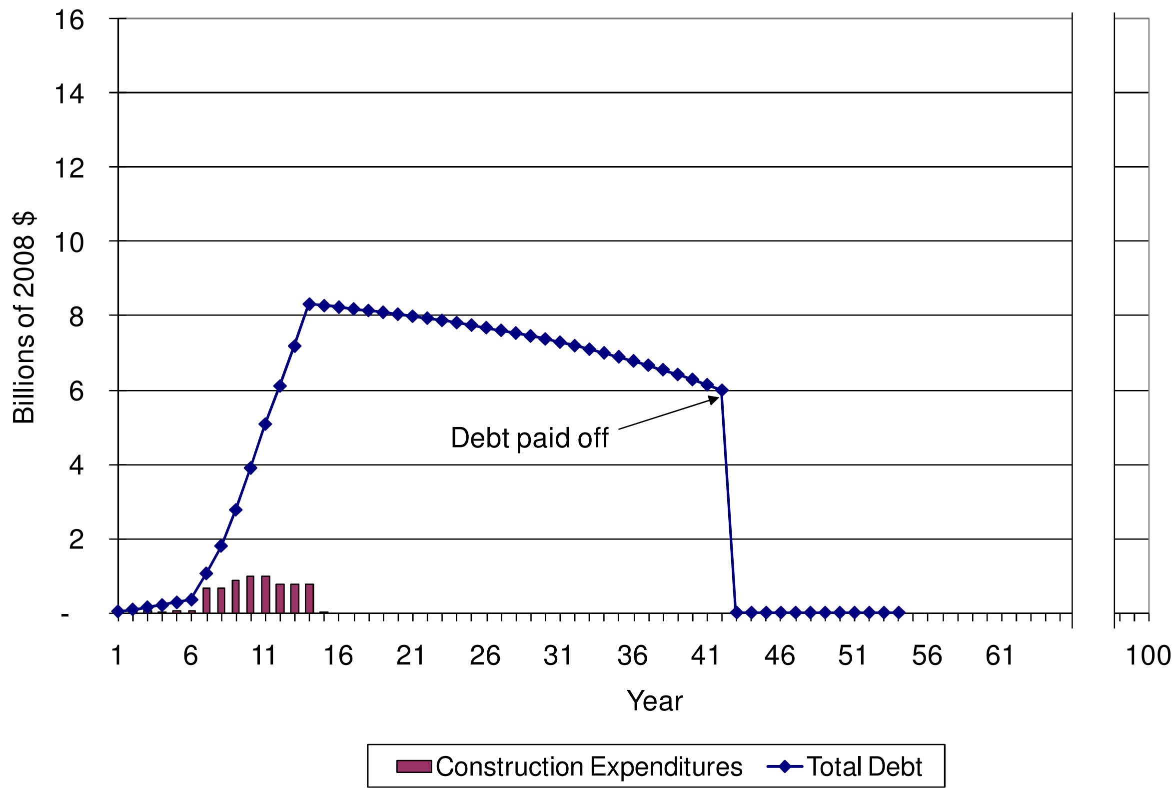


Figure 5.5 Low Watana Annual Construction Expenditures and Total Debt

5.3 Watana/Devil Canyon

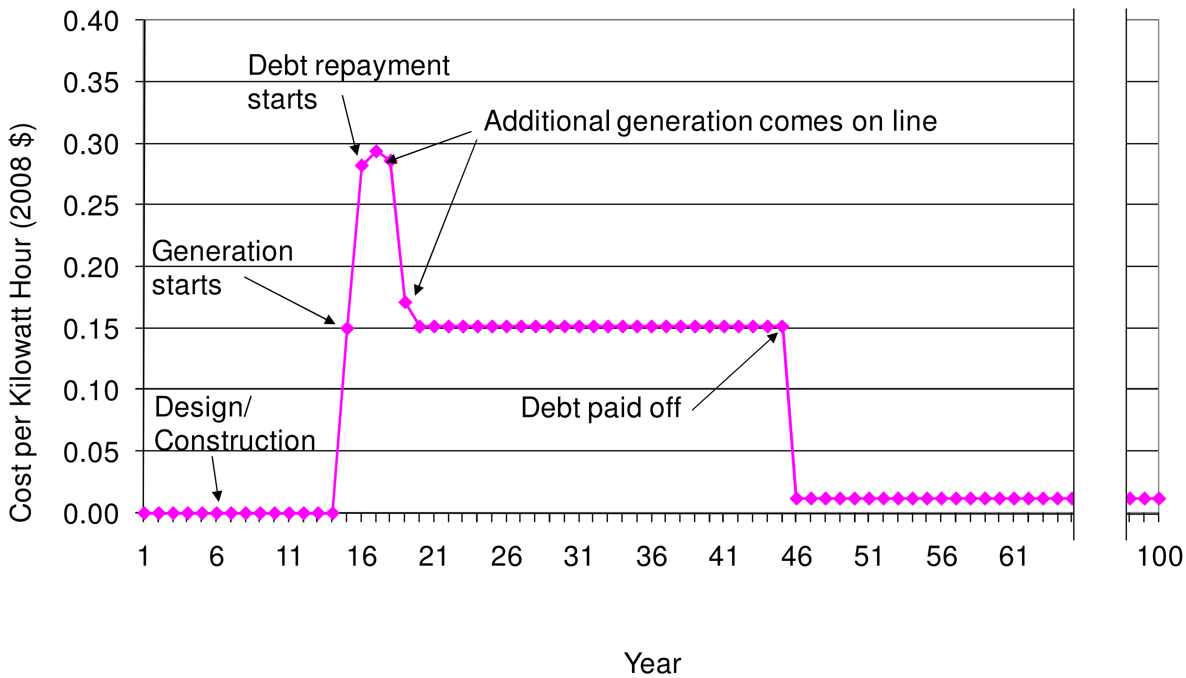


Figure 5.6 Watana/Devil Canyon Cost of Electricity

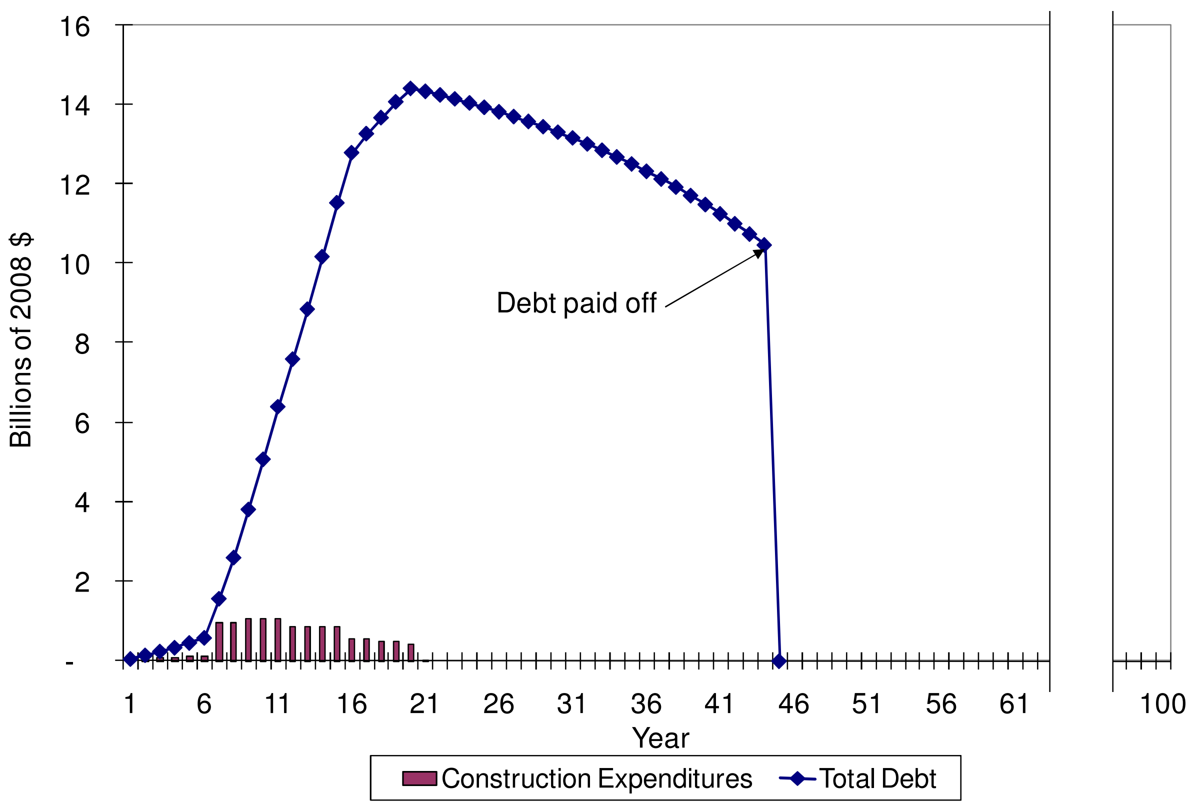


Figure 5.7 Watana/Devil Canyon Annual Construction Expenditures and Total Debt

5.4 Staged Watana/Devil Canyon

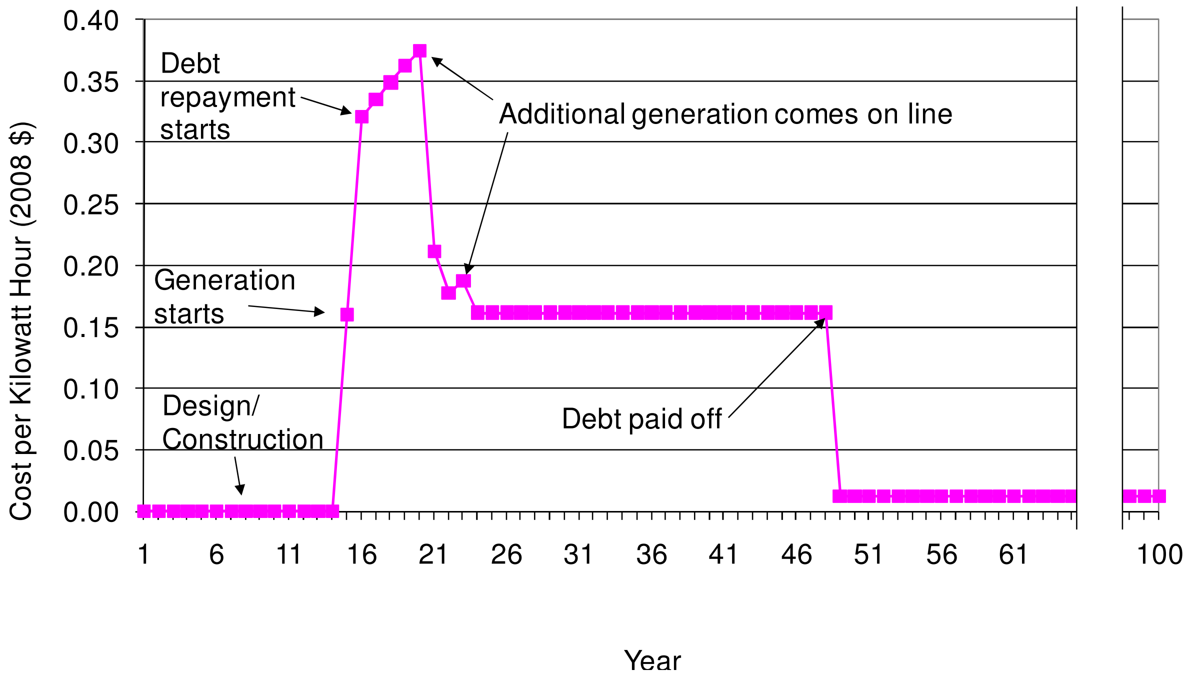


Figure 5.8 Staged Watana/Devil Canyon Cost of Electricity

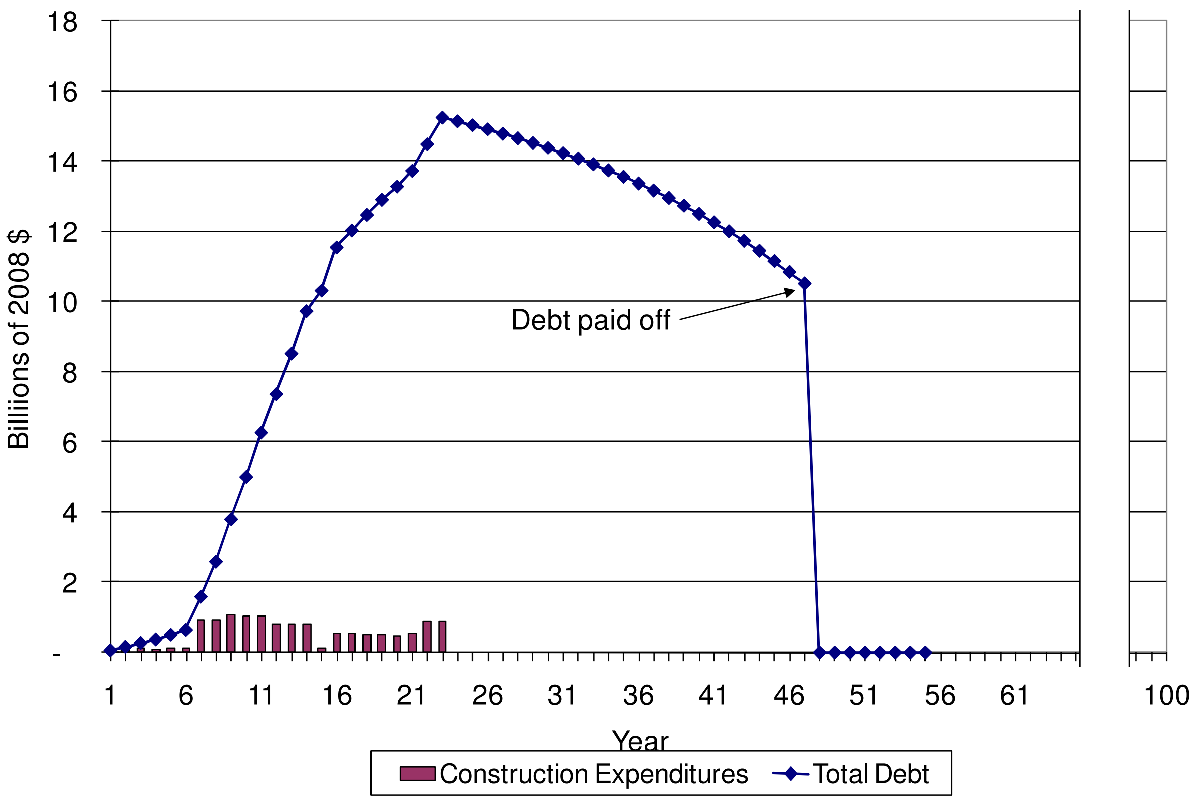


Figure 5.9 Staged Watana/Devil Canyon Annual Construction Expenditures and Total Debt

5.5 Devil Canyon

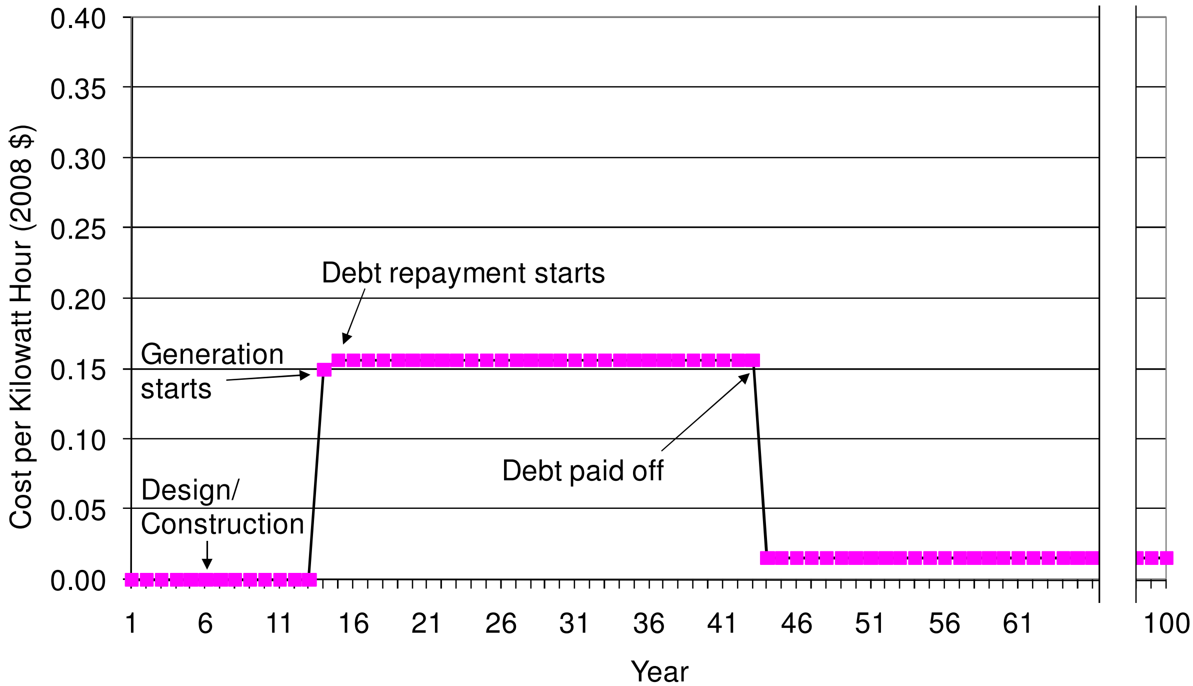


Figure 5.10 Devil Canyon Cost of Electricity

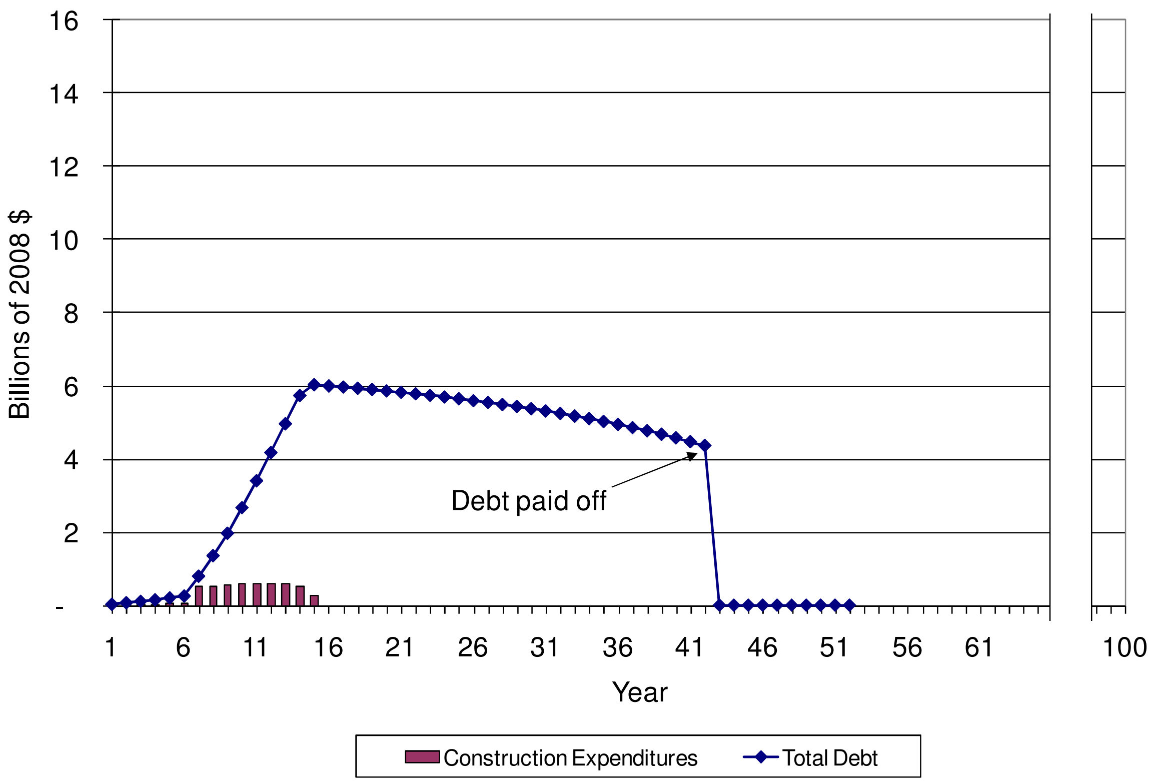


Figure 5.11 Devil Canyon Annual Expenditures and Total Debt

6 Regulatory and Environmental Issues

After the Susitna project was discontinued in 1986 a database of 3,573 documents was created. In September 2008, the 87 most-relevant documents were scanned into HDR's files, of which 18 were summarized. A synthesis of the 7 most-pertinent documents was completed. Because not all of the documents were summarized, some relevant information has likely been overlooked; however, most information was included in the synthesis.

These documents contain information on potential impacts of the proposed project and mitigation proposals for those impacts. Specifically, the documents deal with fisheries resources, botanical resources, wildlife resources, and cultural resources in the potential project area. The documents divide the Susitna River Basin into 4 geographic regions:

- Impoundment zones
- Middle Susitna River
- Lower Susitna River
- Access roads and transmission lines

The potential impacts and mitigation options are discussed for each category in each geographic region as much as possible. It is important to note that not all categories will be impacted in all geographic regions. Mitigation for the proposed impacts is divided into the following categories: avoidance, minimization, rectification, reduction, and compensation. Avoidance is always the preferred mitigation, though it is not usually feasible. Compensation is the only mitigation option for many of the impacts.

6.1 Fisheries Impacts

The fisheries resources have the potential to be impacted the most due to the project. In the impoundment zones, 82 miles of riverine habitat will be transformed into reservoir habitat. The potential exists for the displacement of approximately 20,000 Arctic grayling larger than 8 inches in length from the creation of the reservoirs.

Most of the potential impacts will occur in the middle Susitna River. There will be impacts due to changes in water quality, thermal activity, the water's suspended sediment load, reservoir draw-down fluctuations, impoundment zone inundation, flow regime, and fish habitat. These impacts will result in both positive and negative effects on fish populations. For example, the increase in winter water temperatures will lead to the creation of more overwintering habitat and thus greater fish survival; however, the cooler spring water temperatures will slow fish growth.

Mitigation for these impacts is proposed by compensation through land acquisition, habitat modification, and reservoir stocking.

6.2 Botanical Impacts

The project area contains 295 vascular plant species, 11 lichen genera, and 7 moss taxa. Low Watana inundation will permanently remove 16,000 acres of vegetation. Devil Canyon inundation will permanently remove 6,000 acres of vegetation. Watana inundation will permanently remove an additional 16,000 acres of vegetation. There will be a total of 38,000 acres of vegetation permanently removed. Most of the vegetation inundated will be spruce forest. An additional 836 acres of vegetation will be permanently removed due to access road construction. The transmission corridor will comprise a total of 11,000 acres. Of that area, only a negligible fraction of vegetation will be totally removed due to intermittent placement of control stations, relay buildings, and towers.

There will be limited botanical impacts downstream from the reservoirs. These involve changes to the vegetation due to a more stable environment. Due to flow regulation there will no longer be major flooding events, which destroy the riparian vegetation; instead; rather, there will be succession of the riparian vegetation and colonization of new floodplains. The increase in winter water temperatures will decrease the amount of ice scouring that occurs, which will result in effects similar to those caused by the decrease in flooding.

Botanical resource mitigation will consist largely of compensation for permanently removed vegetation.

6.3 Wildlife Impacts

Within the Susitna River Basin there are 135 bird species, 16 small-mammal species, and 18 large-mammal and furbearing species. There will be 5 classes of potential impacts to terrestrial vertebrates:

- Permanent habitat loss, including flooding of habitat and covering with gravel pads or roads
- Temporary habitat loss and habitat alteration resulting from reclaimed and revegetated areas such as borrow pits, temporary right of ways, transmission corridors, and from alteration of climate and hydrology
- Barriers, impediments, and hazards to movement
- Disturbances associated with project construction and operation
- Consequences of increased human access not directly related to project activities

Mitigation for the proposed impacts involve mostly compensation since there will be permanent habitat loss for most species.

6.4 Cultural Resource Impacts

Within the proposed project area, 297 historic and prehistoric archaeological sites were located. An additional 22 sites were already on file. Sites located within 500 feet of the reservoir's maximum extent may be indirectly impacted due to slumping from shoreline erosion. Indirect impacts may also result from vandalism due to increase in access to the sites. The project has the potential to impact 140 sites. None of these sites will occur in the proposed road corridor or transmission lines. The majority of these sites are relatively small prehistoric sites.

Mitigation for the lost cultural resources will mostly occur through data recovery. Preservation would also be used for some sites. Options to consider include construction of protective barriers to minimize erosion, controlled burial, or fencing of the site to restrict access.

Currently, there are a variety of federal, state, and local land use plans that encompass the Susitna Basin.

6.5 Carbon Emissions

According to the United Nations working group on carbon emissions from freshwater reservoirs the worst case carbon emissions from a reservoir in a boreal climate is 6.7[1] grams per square meter per year. For the Watana/Devil Canyon alternative this equates to 465,000 metric tons of carbon per year or 0.065 metric tons per MWhr. The US Department of Energy reports the average carbon emissions due to electric generation for the State of Alaska to be 0.626[2] metric tons per MWhr. Operation of the Susitna project has the potential to eliminate up to 4 million metric tons of carbon production per year.

[1] United Nations Educational, Scientific and Cultural Organization. Scoping Paper: Assessment of the GHG Status of Freshwater Reservoirs. April 2008

[2] http://www.eia.doe.gov/cneaf/electricity/st_profiles/alaska.html

7 Summary

Table 7.1 provides an estimate of capacity, construction cost, energy, schedule, and cost per kWh for each of the alternatives. Environmental and regulatory issues are substantial and will require comprehensive investigation, though no fatal flaws are apparent based on this initial review. All of these estimates are preliminary, pending more detailed engineering, environmental, and regulatory studies.

Table 7.1 Summary

Alternative	Ultimate Capacity (MW)	Construction Cost ($billion)	Energy (billion kWh/yr)	Schedule (years)	Cost per kWh ($)	
					First 50 Years	Second 50 Years
Watana	1,200	8.4	3.1	15 – 16	0.22	0.01
Low Watana	600	6.9	2.4	14 - 15	0.20	0.01
Watana/Devil Canyon	1,880	11.7	7.2	15 - 20	0.14	0.01
Staged Watana/Devil Canyon	1,880	12.8	7.2	14 - 23	0.18	0.01
Devil Canyon	680	5.0	2.9	14-15	0.13	0.02

Hydroelectric power has many economic and environmental benefits including long-term rate stabilization. Because the cost of the water to power a hydroelectric turbine is essentially free the cost per kilowatt hour is related to the construction and maintenance costs of the dam and powerhouse facilities. As we have seen recently, the price of fossil fuels can fluctuate dramatically over time whereas the cost of hydroelectric power decreases once the initial investment has been repaid and remains low and stable for the life of the project. Consequently the economic risk associated with hydroelectric power is substantially lower than thermal power. Additionally, the life cycle carbon dioxide production of hydroelectric facilities is orders of magnitude less than thermal power plants.

8 Recommendation

The Watana/Devil Canyon alternative is the most cost effective per unit of energy. The Devil Canyon alternative does not provide a stable winter energy supply although its cost per kWh is lower than the other alternatives.

A primary assumption of this report is that all power from these alternatives can be used at the time it is produced. Determination of the need for this power will be dependent upon further studies in conjunction with the Railbelt IRP.

Appendix A

Energy Analysis
Input and Results

Appendix B

Detailed Cost Estimates

Appendix C

Detailed Schedules

Appendix D

Economic Analysis
Input and Results