BUSINESS CASE SUMMARY

Project No.: DESJ0016
Facility Name: Des Joachims G.S.
Project Title/Description: Turbine Runners – Replace runners

1. RECOMMENDATION

Full release approval of $22.7M (Phase 2) to replace the eight turbine runners with modern runners designed to match the site specific hydraulic characteristics of Des Joachims G.S. These runners are at end of life and have suffered from severe and excessive cavitation damage since installation due to the mismatch of the runner and the hydraulic characteristics of the station. There is a significant risk of catastrophic failure due to the cracking damage which has become more evident during the past few repair cycles. New turbine runners will eliminate excessive cavitation damage, weld repairs and related production losses while also increasing turbine efficiency and annual energy production.

Definition Phase approval (Phase 1) was attained in 2004 of $1.1M to develop and test a model turbine runner and obtain proposals to supply eight turbine runners over the period from 2007 to 2014. American Hydro Corporation was the successful bidder (of five turbine manufacturers) on a Request for Proposal (RFP # EP-HBU-2004-001). To date, model development is complete with model testing and OPG independent lab testing to be conducted from March – June 2006 at IMHEF Ecole Polytechnique (Lausanne Switzerland).

Total project cost (including $91k spent to date of the $1,100k previously released) is $23,800k

M$	Pre 2006	2006	2007	2008	2009	2010	2011-15	Total
Recommended Alternative	$77k	$2.2M	$2.6M	$2.8M	$2.7M	$2.7M	$10.7M	$23.8M
2006-2010 WPC Final Budget	$110k	$1.2M	$1.6M	$2.2M	$2.2M	$2.2M	$9.7M	$19.1M
Variance to Business Plan	$33k	(1.0)	(1.0)	($0.6)	($0.5)	($0.5)	($1.0)	($4.7)

Expenditure Type: Capital
Investment Type: Sustaining/Value Enhancing
Release Type: Full release under OAR element 1.1.2

Funding: 2006 - 2010 Work Program Catalogue (WPC) Final Budget: $19,147k is the current estimate for project costs in the 2006-2010 WPC Final Budget. Definition Phase release of $1,100k was approved in 2004 to develop, construct and test a model runner designed to match the site specific hydraulic characteristics of Des Joachims G.S. The increased cost of this release includes additional unit components that directly relates to the operation and performance of the new turbines and require rehabilitation. This increased funding will be managed within the OSPG Capital budget envelope. Subsequent years will be re-programmed into the Work Program Catalogue during the next business planning cycle. Total overall project costs including definition phase will be $23,800k

Investment Financial Measures: NPV: $3,862k (Relative to the Base Case)

2. SIGNATURES

Submitted by:

Plant Group Manager – OSPG date Apr 26/06

Recommended by:

EVP – Hydro date May 3/06

Finance Approval:

SVP & Chief Financial Officer date

Line Approval per OAR 1.1.2:

President & CEO date May 3/06

3. BACKGROUND & ISSUES

- Des Joachims GS is an eight unit, hydroelectric station located on the Ottawa River, 20km north of Deep River. The facility was placed in service in 1950 and 1951. The station is controlled from the Chenaux Control Centre. The station capacity (MCR) and average annual energy production are 428.8 MW and 2,247 GWh respectively. The ten year average of the station Capacity Factor is 58%.
- The asset classification of this station is a Flagship. It is ranked 4th in both capacity and energy production in Hydroelectric. The Life Cycle Plan capital expenditure strategy for this station includes planned investments, over the next 30 years, totalling about $75 million: $50 million for capital and $25 million for Non-Standard OM&A. Major projects include the turbine replacement program ($24M), rehabilitation of sluice gates ($17M), generator rewind program ($6M), replacement of generator and transformer protections ($3M), replacement of switchgear ($2.6M), replacement of station service transformers ($1.6M), repair main dam concrete ($1.2M), replacement of stoplogs ($1M) and roof replacements ($0.6M).
- Reliability has been excellent over the past 10 years with an Incapability Factor (ICbF) in the 7% range. The ICbF is expected to increase to about 10% from 2007 to 2015 during these planned outages. After 2015, the ICbF is expected to average 6%.
- The Equivalent Forced Outage Rate (EFOR) is near excellent and any delay of the turbine replacement program could negatively impact the current EFOR rate.
- The main driver of this project is runner cavitation protection and the need to replace the end of life runners and reduce the current runner repair program. In addition to the cavitation protection, the contract obligations expect a [redacted] efficiency gain.
- This facility participates in the Independent Electricity System Operator (IESO) Automatic Generator Control (AGC) program which acts to match total system generation to total system load as required on the electricity grid, and helps correct variations in power system frequency. This service causes the unit outputs to vary automatically within a specified range, in response to control signals from the IESO's Energy Management System (EMS). The average weighted efficiency of the existing turbines is less than the proposed design of the new turbines. In other words, there will be a greater band of unit efficiency with the new design that the operations of these generators are subjected to due to AGC control.
- There is a need to restore the integrity of the turbine runners at Des Joachims G.S. to ensure reliable operation of the unit generators. The existing Francis runners at Des Joachims G.S. were purchased in 1975 as replacements for the original runners to increase the output and efficiency of the units. The efficiency was increased by [redacted] and the unit outputs were increased by [redacted] (best efficiency) and [redacted] (full load). These new runners were not custom designed for Des Joachims G.S.; they were "off the shelf" runners with no homologous model testing and are near end of life. Sustaining the present conditions will become more and more difficult with outage repairs increasing approx. 20% per year.
- The runners can be repaired based on the existing 4 year maintenance cycle of 12 weeks for two units but the following will occur:
    - Cavitation damage will worsen.
    - Additional blade cracking will occur in the transitional area at the crown and runner band due to blade profile changes.
    - Maintenance outages will be longer with each repair as runner condition worsens.
    - Increased damage and repairs will change the hydraulic profile of the blades and further accelerate the aging of the runners.
    - Loss of efficiency.
- Maintenance outages for runner repairs are no longer technically viable and economically limiting. Due to their very poor condition, the runners will require extensive repair work to keep them operational until they are replaced. The additional runner repair work will significantly increase base maintenance costs by $150k to $250k per year (or by 15% per cycle) until the runners are replaced. This welding has resulted in distorting the runner blades and recently, significant fatigue cracks have been identified at the runner crown/blade transition and the runner band/blade interface. Unit 7 (2001) had 10 of 15 blade cracks. Unit 1 (2002) revealed 3 of 15 blades with cracks. The cracking is resulting from the blades fluttering which in turn is caused by the distorted blade profile.

- This cavitation and cracking damage will determine the schedule of the replacement runners.
- Due to IESO unit outage restrictions and Plant Group experience, it is virtually impossible to schedule two outages per year. OSPG has experienced difficulty in obtaining outages from the IESO. In the recent past, the IESO frequently requested delays of the start dates of planned outages for runner replacement. Each day of delay compromises the completion date and the return to service of each unit.
- The position of OPG and OSPG is to avoid commercial losses associated with water spill during spring freshet. Generating units will not be removed from service during periods of high water flow. Units will be made available, during this period, to generate all potential energy.
- During the runner replacement program, other work, classified as OM&A (Mechanical/Electrical Overhauls - DESJ0008) is required to return units to satisfactory service. In other words, while the units are disassembled, it is an opportune time to repair and realign various parts of the units.
- Five of the eight generators recently had stator winding replacements. It is recommended the remaining three units (G1, 3 & 5) be scheduled to coincide with the last three turbine outages. Risk associated with this deferral is fairly low due to the fact that Partial Discharge (PD) test results are proving that these winding are in fair condition for their age. This will extend the life of the winding of these units to approximately 40 years.
- IMHEF Ecole Polytechnique (Lausanne Switzerland) will be conducting a full homologous model test to guarantee the performance of a new runner. If the test results indicate that the new runners are not as good as guaranteed of the Phase 1 bid, liquidated damages ([redacted]) could be awarded as per contract obligations.
- The time required to attain BCS approval, generate the Purchase Order and manufacture a new turbine following the acceptance of the model test results, is limited. The approval of this release will proceed with expectation that the turbine model tests results will meet the contract guarantees and Phase 2 of the turbine project will proceed. If funding approval is not acquired by May 2006, the schedule of the first unit outage will be compromised as describe below in the Risk table.
    - **Design and Manufacture Model** – Start Sept. 1, 2005 / Complete March 17, 2006
    - **Install and Test Model** – Start March 27, 2006 / Complete June 20, 2006
    - **Manufacture Proto-type Turbine** – Start July 7, 2006 / Complete Sept. 21, 2007
- All costs associated with the unit disassembly, re-assembly, testing and commissioning to return the unit back to service will be charged against the capital portion of each outage.

- **Phase 1 -** Design, development, testing and demonstration of performance by witness test of a Francis turbine runner model (including the existing stationary parts: penstock, spiral casing with stay ring, turbine wicket gate mechanism, turbine bottom ring, discharge ring and complete draft tube) and delivery of the complete model to an independent laboratory for acceptance tests. Total cost $1,100k - completion date June 20, 2006

- **Phase 2 -** Upon successful completion of the model development phase and final acceptance testing at the independent laboratory, American Hydro Corporation to manufacture 1 prototype runner - completion date Sept. 21, 2007, and supply up to (8) full size Francis turbine runners, including the proto-type runner, nose cones and 8 sets of runner to shaft coupling bolts for Des Joachims GS.

4. ALTERNATIVES & ECONOMIC ANALYSIS

Base Case: (Status Quo)
Do nothing - Continue with present four year runner maintenance repair cycles and operate the generating units as is.
This alternative is not recommended since runner maintenance repair outages will be longer with each repair. The repair regime on these runners has accelerated the aging of the runners and they are quickly approaching their end of life. The present repair strategy will not resolve the cavitation problems but accelerate the damage, blade cracking, blade profile distortion and reduction in turbine efficiency. Possibility of catastrophic turbine runner failure could occur resulting in significant lost production.
This alternative rejected due to the efficiency loss, asset protection and the extended outage durations required for runner welding repairs.

Alternative 1: Perform Major Repairs and Defer Runner Replacement to Start in 2018
A program to rehabilitate the runners would be undertaken between 2007 & 2014 and the runner replacement program would be implemented starting in 2018. Each runner would be removed from the unit and extensive repairs performed in a controlled environment on the generating station floor or machine shop, one runner per year with an outage length of 22 weeks and a cost of $514k. This alternative will not bring the runner blades back to their design profile nor relieve the built-in stress from welding repairs. Long term use of the existing runners will also jeopardize the throat ring.
This alternative is considered but rejected. NPV calculations indicate that this alternative is not economically beneficial.

Alternative 2: Replace 8 Runners Over 5 Years 1, 2,2,2,1 (2007-2011)
Install 1 runner in years 2007 and 2011, and 2 per year between 2007 and 2011. The second outage is scheduled to allow for performance testing of the first runner and verify performance guarantees. Once the efficiency of the new turbine has been measured the program is accelerated to two runners per year.
This alternative is unacceptable due to IESO outage restrictions and scheduling conflicts with spring freshet conditions and summer/winter peak demands as discussed in section 3. Background and Issues.

Alternative 3: Replace 8 Runners 1 per Year (2007- 2014)
The primary deliverable is the supply and installation of 8 new Francis Turbine Runners (1 per year between 2007 and 2014), nose cone and coupling bolts, designed to match the site specific hydraulic characteristics of Des Joachims GS. Components directly relating to the Turbines and require inspection or rehabilitation are as follows; Throat Ring, Headcover Wearing Plates and Seals, Turbine Bearing and Journal, Runner Shaft Seal and Turbine Shaft coupling faces. Unit disassembly, re-assembly, set up and in service testing needed to return the unit generator back to service will all be charged against this release. Also included; Final Report - A description of the work done including all measurements taken during the outage and commissioning test results, Post upgrade Performance test and report.
Highest probability of obtaining IESO approval for unit outages is during Aug.-Nov. period. This outage period will avoid units being out of service during spring freshet and summer/winter peak demands.
This is the recommended alternative

Financial Analysis

	Base Case	Alt. 1	Alt.2	Alt.3
Initial (k$)	4,286	32,151	22,255	22,437
NPV (2006 PV (k$) 30 years	(8,691)	(10,156)	(5,383)	(4,829)
Impact on Economic Value (2006 PV k$)		(1,465)	3,308	3,362

5. THE PROPOSAL

Results to be delivered

- Install eight new turbine runners to improve unit efficiency and enhance runner cavitation protection thus resulting in less maintenance outage time required to repair the turbine runners. Eliminate in place welding repair costs per unit @ $150k - $250k each and total commercial losses estimated at $490k to conduct repairs for two runners per year.
- The new runners are designed to be virtually cavitation free, thus eliminating in place welding repairs.
- Expected unit generator improvement performance resulting in the runner program is [redacted] efficiency gain, which results in an increase in station output by 52.6 GWh/yr
- One additional performance test (post upgrade) will be completed in 2008 and efficiency curves will be produced.
- PIR will be conducted in 2008 following the first turbine replacement outage and prior to commencement of second outage.

Milestone	Turbine Replacement Completion Date	Turbine Manufacturer Completion Date
Runner Model Development & Independent Lab Test	2005/2006	
G3 Pre upgrade Performance Test	2005 (Complete)	
G7 Pre upgrade Performance Test	September 2006	
G7 Runner Replacement	November 2007	G7 September 2007
G7 Post upgrade Performance test	March 2008	
G7 Simplified PIR	June 2008	
G2 Runner Replacement	November 2008	G2 September 2008
G6 Runner Replacement	November 2009	G6 September 2009
G4 Runner Replacement	November 2010	G4 September 2010
G8 Runner Replacement	November 2011	G8 September 2011
* G1 Runner Replacement	December 2012	G1 September 2012
* G5 Runner Replacement	December 2013	G5 September 2013
* G3 Runner Replacement	December 2014	G3 September 2014
Comprehensive PIR	2015	

* Last three runner outages will include a stator rewind, extending the outage window approx. 8 weeks.

Project Management

- A Project Execution Plan (PEP) will be used to monitor the project progress.
- Lessons Learned meetings will be conducted following each outage and a list of actions developed will be implemented on the subsequent outages. The PEP will be revised and issued by Q2 of each outage year.

6. QUALITATIVE FACTORS

- The new turbine runners should be designed to be "virtually maintenance free", E.g. excessive cavitation damage elimination and increase turbine efficiency and annual energy production.
- Resource feasibility study conducted in 2005 determined the availability of a combination of experienced Des Joachims and other OSPG staff supplemented with BTU labour working two ten hour shifts would reduce the outage time from 20 weeks to 13. The Project Engineer will co-ordinate work between PWU staff and any contractors.
- The work assignment will be as per Chestnut Park Accord process.
- The stations reliability will be sustained by reducing future forced outages caused by runner failures.
- Economic viability and continued availability of revenue of the asset will be maintained and protected.

- The project will comply with Ottawa/St.Lawrence Plant Group Environmental Managed System/Occupational Health and Safety Managed System and related Ottawa/St.Lawrence Standing Instruction/Station Specific Standing Instruction Procedures.

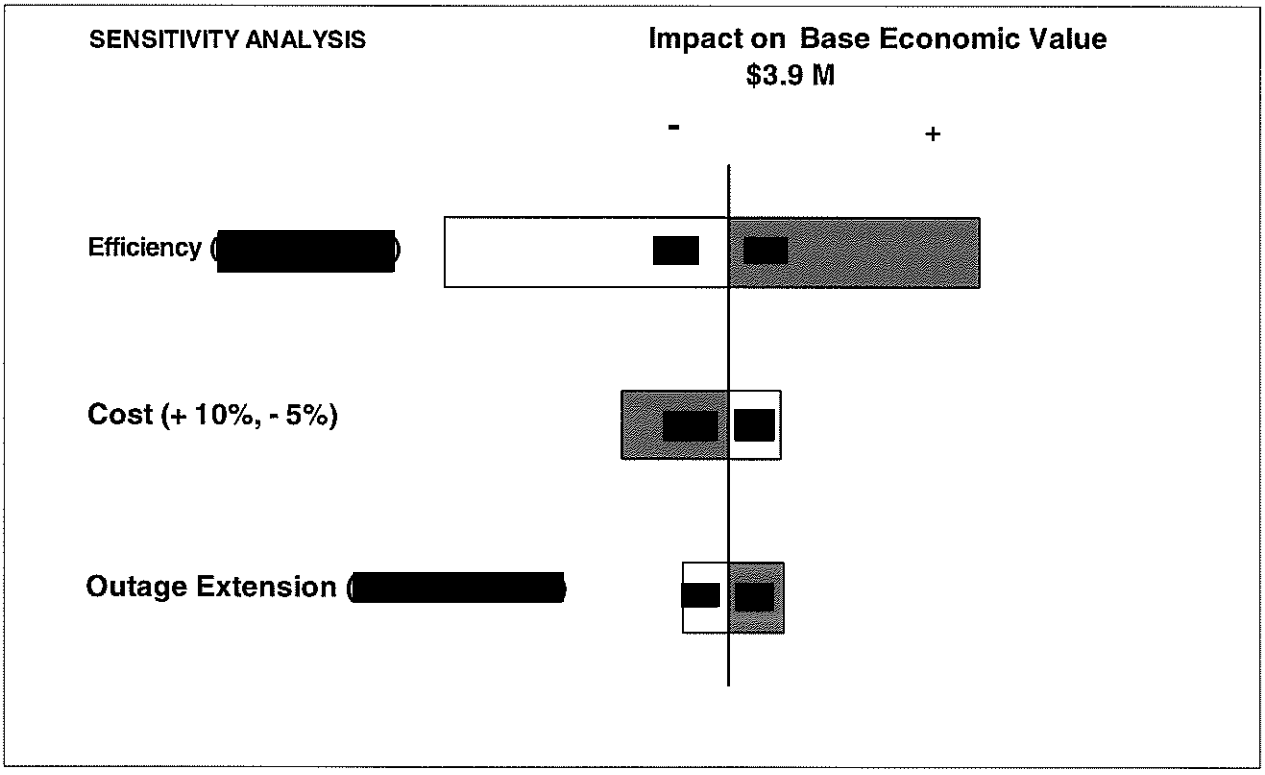
7. RISK ANALYSIS

Risk Description	Impact	Initial Risk (before Mitigation) (H,M,L)	Mitigating Activity	Residual Risk (after Mitigation) (H,M,L)
Cost				
1. Runner costs increase including steel cost escalation.	1. Exceeding release amount.	1. M	1. The financial risk for the runner costs is minimal since runner cost escalation has been identified and included in the cash flows.	1. L
2. Escalation to PWU/BTU labour rates.	2. Exceeding release amount.	2. M	2. An OPG/PWU contract obligation for the following 3 years guarantees the labour rates for the first 3 outages. Contingency funds will protect against future contact labour rate increases.	2. L
Scope				
1. Emergency repair of damaged equipment upon disassembly.	1. Increase in cost to repair damaged equipment.	1. M	1. Have the staff experience with the previous runner changes, therefore know what to expect.	1. L
2. Units become unavailable due to existing runner failure.	2. Loss of generation and revenue	2. M	2. Runner failure will be evident throughout the runner change program. Runner welding maintenance will continue throughout the runner change program. Inspections of the remaining runners will determine the priority of the outage schedule taking into account units that have higher probability of failure.	2. L
3. Deficiencies to equipment unknown until unit is dismantled and inspected.	3. Exceeding release amount and outage schedule.	3. M	3. [redacted] project contingency will be included for the first unit (excluding the runners) to cover the cost of these items. A [redacted] reduction in contingency each year down until year 2011 and will remain at [redacted] for the remainder of the project. The runners will have a [redacted] contingency for the life of the project. **Stationary runner seals -** These seals shall be inspected upon removal of the runner from the unit. One new set of seals will be pre-machined and ready for final machining. The new runners will dictate the sizing and allowable tolerances. **Throat ring** - Inspect upon removal of the runner with welding/machining repairs as required. Past throat ring inspections have indicated only minor welding repairs required.	3. L
4. Accelerate the runner replacement program and conduct two runner replacements a year due to catastrophic failure of an existing runner.	4. Second runner not available.	4. M	4. Runner supplier could revise the manufacturing schedule and produce two runners per year at a cost premium.	4. L

Schedule				
1. Unable to remove unit from service.	1. Delays the start of each outage and shifts costs to future years.	1. M	1. Start the outage as requested to follow timeline of critical path.	1. L
2. Delay acquiring Businesses Case Summary approval.	2. If the approval of the Business Case is hindered, delivery date of the new runners may be delayed and the outage schedule will be at jeopardised.	2. M	2. Approval of the BCS will be obtained based on the contract guarantees. If the model tests results do not meet the performance guarantees liquidated damages ([redacted] could be awarded and the F.E's will be re-calculated based on the model test efficiency results.	2. L
3. Critical path of the project extended.	3. Exceeds outage request and delays the return to service date.	3. M	3. Long lead time items identified in the project charter and will be purchase prior to the commencement of the outage.	3. L
4. Runner delivery date not met.	4. Exceeds outage request and delays the return to service date.	4. M	4. Repair original runner and place back in service.	4. L
Resources				
1. Lack of PWU resources	1. Lengthen the unit outage	1. M	1. Resource feasibility study conducted in 2005 determined a combination of Des Joachims and other OSPG staff supplemented with BTU labour would reduce the outage from 20 weeks to 13.	1. L
Technical				
1. Will not meet expected performance guarantees.	1. Less than expected revenue due to reduced efficiency gains.	1. M	1. There is the potential that the full-scale prototype runner may not meet its performance guarantees and in this case, liquidated damages can be applied. ([redacted]. G7 pre-upgrade performance test results will be used as the baseline for the remainder of all units. Post upgrade performance test conducted on G7 will verify the efficiency gains.	1. L
2. Catastrophic failure of an existing runner	2. Unit unavailable for approx. 12 months due to the time required to manufacture a new runner.	2. M	2. Current runner repair cycle will continue during the runner replacement program	2. L
Health & Safety				
1. Fall protection	1. Extended outage time	1. M	1. Falling hazards have been eliminated or controlled as part of the project with installation of scaffoldings, improving employee safety.	1. L
2. Regulatory requirements.	2. Work stoppage.	2. M	2. A detailed inventory of all manufactured, and/or engineer approved OPG/OSPG fabricated lifting device have been approved for use at Des Joachims GS.	2. L
Investment				
1. Guaranteed cavitation protection of a new runner will not be met.	1. Cavitation performance will not be met. There is no capacity increase for the units but there is increased cavitation protection that results in significantly reduced maintenance costs.	1. M	1. Runners shall be guaranteed against cavitation for a period of 15,000 hours of operation. The full cost of repair and any modifications required to reduce or eliminate subsequent cavitation damage will be the responsibility of the runner manufacturer.	1. L
2. Runner defects	2. Unforeseen outages and associated costs required to repair or replace a defective runner.	2. M	2. Except for cavitation damage the runner will be safeguarded against defective parts, design, material or workmanship up to five years as per the contract document.	2. L

The results of the sensitivity analysis are shown in the diagram below. This shows the variance from the preferred option (Alt. 3) NPV ($3,862M) resulting from changes to Efficiency, Cost and Schedule. Differences in NPV from the preferred option assumptions (plus and minus) have been plotted. The diagram illustrates that Efficiency represents the greatest risk of influencing the NPV value with Cost and Schedule expected to present the least risk.

VARIABLE/RISK	HIGH/LOW RANGES	+/- FROM BASE ECONOMIC VALUE (2006 $M)
Efficiency Gain	HIGH [redacted] **TARGET** [redacted] LOW [redacted]	[redacted]
Cost	HIGH 10% increase LOW 5% decrease	[redacted]
Outage Extension	HIGH 20 weeks LOW 8 weeks	[redacted]



8. POST IMPLEMENTATION PLAN:

- Pre-Upgrade Performance tests on G7 will be used as a baseline to verify the efficiency gains of all the units. Post-upgrade performance tests on G7 will be conducted in 2008 and the efficiency improvement for the new runner will be derived from the G7 post-upgrade tests.
- The new runners will be inspected annually for cavitation damage by OSPG staff.
- Warranty cavitation inspections will be conducted following 15,000 hours of operation (Approx. 3 years) and witnessed by American Hydro as outlined in the Contract Terms and Conditions.
- Four year cycle of current runner welding repairs will be reduced and the decrease in costs associated with these repairs will be verified at the conclusion of the program.
- Simplified PIR will be conducted following the first turbine replacement outage - Q1 2008.
- The final PIR report will be completed by the Ottawa/St. Lawrence Plant Group Asset Management Department - May 2015.

ONTARIO POWER GENERATION

HYDROELECTRIC
Summary of Estimate

Date	April 2006
Project #	**DESJ 0016**

Facility name: Des Joachims Generating Station

Project Title: Turbine Runners – Replace runners

Years	Pre-2006	Y2006	Y2007	Y2008	Y2009	Y2010	Y2011	Y2012	Y2013	2014	2015	TOTAL	%
Project Management and Engineering **(012)**	$31k	$50k	$51k	$52k	$53k	$54k	$55k	$56k	$57k	$59k	$60k	$578k	2
Materials **(200)**	[redacted]												
Consultant **(310)**	$38k	$150k		$104k								$292k	1
Construction/Installation													
Hydroelectric (PWU) **(010)**	$8k	$10k	$326k	$333k	$340k	$346k	$353k	$360k	$368k	$375k	$30k	$2849k	12
Others (BTU) **(310)**	[redacted]												
Interest **(700)**		$113k	$139k	$146k	$142k	$145k	$148k	$150k	$153k	$116k	$11k	$1263k	5
Contingency **(998)**	[redacted]												
TOTAL (GROSS)	$77k	$2200k	$2623k	$2800k	$2700k	$2700k	$2700k	$2800k	$2800k	$2200k	$200k	$23800k	**100%**

Notes: 1 Schedule Start Date Aug. 2007
Final In-service Date Feb. 2015

2 Interest (6%) and escalation (2%) rates are based on current allocation rates provided by Corporate Finance

3 Includes removal costs of: $80k

4 Includes Definition Phase Cost of: $1,100k

Prepared by: Ron Grosell	Approved by: R Marsh
Project Engineer RON GROSELL	Project Manager
Date: APRIL 11/06	Date: APRIL 25/06