# Seawater Reverse Osmosis – The Most Cost Effective Alternative for Meeting Nassau's Near Term Water Needs

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## Background

To address a projected near term shortfall in water supply and to satisfy system demands for the next five to ten years, the Water and Sewerage Corporation (WSC) solicited bids for a 6 migd seawater reverse osmosis desalination plant to be installed at its Blue Hills pumping and storage facility. These bids were based on a facility with an initial installed membrane treatment capacity of 5 migd with WSC guaranteeing to purchase at least 4 migd. As system demand increases, the installed treatment capacity will be increased to 6 migd and WSC will agree to purchase 5 migd of desalinated water on a continuous basis. This project will be executed on a Build, Own, and Operate (BOO) basis with the successful contractor providing the project financing, the detailed design, construction, commissioning, and operation of the facility for a period of 20 years. This procurement approach has resulted in competitive proposals that offer a cost-effective solution for WSC's long term supply of potable water.

## Current Water Supply Sources

The current water supply sources for New Providence are summarized in **Table 1**. Approximately 2.5 migd of groundwater comes from wellfields located on New Providence Island. These wellfields generally are of poor quality of with respect to chlorides and total dissolved solids and extraction rates are near the maximum sustainable limits for this reason, WSC would like to reduce withdrawal rates from these wellfields to allow the water quality to recover.

WSC has been importing higher quality water from Andros Island (chlorides less than 300 mg/l). Initially this water was delivered by towing barges between New Providence and Andros. However towing barges in rough seas proved to be difficult. This resulted in higher downtime than desired and increased the overall cost of water. To improve the reliability of this water supply, WSC purchased two self-propelled ocean going tankers. These tankers are manned twenty four hours per day and make approximately two round trips daily from Nassau to Andros. These tankers improved the overall economics of importing water from Andros to approximately $5.50/kigal. However, severe weather conditions can still interrupt water delivery.

In 1996, WSC entered into an agreement with Waterfields Company Limited to finance, design, build and operate a 2.2 migd seawater desalination plant at WSC's Windsor Wellfield. Under the terms of this agreement, WSC guarantees to purchase 2.0 migd of desalinated water from the Windsor Seawater Reverse Osmosis Plant on a seven days per week 365 days per year basis. The initial cost of this desalinated water was $5.75 per kigal. As a result of escalation in fuel prices and other allowed annual cost escalation adjustments, the current price of desalinated water is $6.70/kigal. In order to improve the overall water quality, this facility is designed to produce desalinated water with a total dissolved solids (TDS) concentration of less than 50 mg/l. This desalinated water is then blended with water from the Windsor wellfield to improve the overall water supply quality.

In reviewing WSC current water supply situation, it is important to note that the system currently has a Non-Revenue Water (NRW) component of approximately 50 percent. This means that revenue is actually realized on only 50 percent of the water that is delivered into the system. In response to this situation, WSC has instituted a NRW reduction program. This program currently results in the location and repair of numerous leaks on an annual basis. However, WSC recognizes that further reductions in NRW are required to improve their overall water supply economics.

**Changes in the Water Supply Situation**

One of the tankers that WSC uses to import water from Andros, the Dolphin, is approaching the end of its useful service life and will be retired within the next year. Once the Dolphin is decommissioned, WSC will have a shortfall of approximately 1.6 migd in the water supply from Andros. In addition, due to shortfalls in groundwater supply due to low rainfall and other issues and with additional consumers about to come online, WSC is projecting an additional near term shortfall of 2 migd.

To address this projected near term shortfall and to satisfy system demands, WSC solicited bids for a new 6 migd seawater reverse osmosis desalination plant to be installed at its Blue Hills pumping and storage facility. To alleviate the projected shortfall and meet near term demands, this facility will initially have 5 migd of installed membrane treatment capacity with WSC guaranteeing to purchase at least 4 migd.

The 4 migd of desalinated water from the desalination plant will allow WSC to reduce water imports from Andros. In addition, water withdrawals from the wellfields can be reduced, which will allow the water quality from these wellfields to improve. These changes in the water supply sources will result in an overall improvement in the quality of the water supply.

Typical construction times for a seawater desalination plant of this size range from fourteen to eighteen months. As a result WSC could be faced with a shortfall of 1.6 migd between the time that the Dolphin retires and the time the new desalination plant is constructed. WSC investigated the installation of seawater RO units on an emergency basis for meeting this near term shortfall. Proposals received generally resulted in a water cost in the range of $5.90 to $7.00 per kigal and required a commitment of up to 9 to14 years on the part of WSC. To address this issue, the bidders for the Blue Hills Desalination Plant have offered alternative delivery schedules which would result in bringing additional water supply online in only 6 to 10 months.

**Windsor Seawater Reverse Osmosis Plant**

A similar BOO seawater reverse osmosis facility has been operating successfully at WSC's Windsor wellfield for over eight years. The Windsor Seawater Reverse Osmosis Plant has an installed capacity of 2.2 migd with WSC guaranteeing to purchase 2.0 migd for the fifteen year term of the Agreement. Due to the high cost of electricity (over $0.13/kwh) at the time that this project was bid, it was decided to install diesel engine drives on the high pressure RO pumps. This resulted in a savings of over $1.00/kigal over an all electric powered seawater reverse osmosis plant. The terms of the Agreement for the Windsor project are similar to the terms for the current Blue Hills project, except for the larger production capacity and extension of the contract duration from 15 to 20 years. The scopes of work for both projects include seawater supply boreholes, the membrane treatment facility, concentrate disposal boreholes, a new 5 MIG ground storage tank with interconnection to existing storage tanks. One primary difference between the previous project and the current project is that due to the high cost of electricity, the main membrane feed pumps in the Windsor project were diesel driven. Due to restructuring in the Government, WSC anticipated that they would be able to obtain more competitive electricity rates for this project. For this reason, the diesel driven pumps were changed to electric driven pumps.

## Design Concept Blue Hills Seawater Reverse Osmosis Plant

As discussed, with the retiring of the Dolphin and considering new customers and proposed reductions in groundwater withdrawals, WSC projects that it will have an immediate firm commitment of 4 migd of desalinated water for the new Blue Hills Seawater Reverse Osmosis Plant. In addition, WSC anticipates that there will be periods throughout the year when an extra 0.5 to 1.0 migd of water will be required. In the longer term, it was considered that 6.0 migd of water would be needed from this new seawater reverse osmosis plant. For this reason, it was decided to specify that this plant be designed for an ultimate capacity of 6.0 migd with 5.0 migd of membrane capacity being installed initially. WSC would commit to purchasing 4.0 migd of capacity on a continuous basis and the facility would have reserve capacity to accommodate equipment maintenance and repair and to meet peak seasonal demands.

The scope of this project includes a 6 migd seawater reverse osmosis desalination facility which will be installed at WSC's Blue Hills pumping and storage facility. This new facility will include seawater supply wells, concentrate disposal wells, cartridge filtration, high pressure membrane feed pumps, state of the art energy recovery devices, membrane treatment units, chemical dosing systems, membrane process building, and 5 MIGD of ground storage capacity. The membrane units will have horizontal multistage centrifugal pumps dedicated to each membrane unit. The membranes will achieve in excess of 99.7 percent salt rejection. The flux rates will be less than 9 gallons per square foot per day. The treatment units will be equipped with the latest state-of-the-art energy recovery devices, either pressure or work exchangers. These devices typically recover in excess of 93 percent of the available energy in the concentrate. The system will operate with an overall energy consumption in the range of 11 to 13 kwh/kigal.

The project will be executed on a Build, Own, and Operate (BOO) basis with the contractor operating the facility for a period of 20 years. Performance guarantees will include power consumption, maximum electrical demand, and fuel oil consumption. Performance testing will include operation of the membrane units and demonstration of the performance guarantees at both the guaranteed water purchase amount of 4 migd and the installed capacity of 5 migd.

The seawater reverse osmosis plant will produce finished water meeting World Health Organization Standards with a single pass membrane design. Chlorides will be reduced from approximately 20,000 mg/l in the feed water to less than 250 mg/l in the permeate. The product water will be stabilized using either lime or calcite contactors to achieve a finished water hardness of over 50 mg/l with an alkalinity of over 40 mg/l as $CaCO_3$. The finished water will be disinfected using calcium hypochlorite.

## Blue Hills Bid Results

The Blue Hills Seawater Reverse Osmosis Project was advertised in December 2003 and the prequalification process was completed in January 2004. Eight (8) firms were prequalified; and bids were received from five firms in March 2004. The bid prices for the base bids are summarized in the following table:

| BASE BID 4 MIGD | CONSOLIDATED | BIWATER | IONICS* | IDE | ENERSERVE |
|---|---|---|---|---|---|
| Bid Price (B$/kigal) | $2.420 | $2.930 | $3.398 | $3.615 | $4.503 |
| Evaluated Price (B$/kigal) | $4.413 | $4.758 | $5.235 | $5.817 | $7.092 |
| Capital Cost (B$1000) | $18,463 | $21,034 | $32,300 | $28,000 | $45,052 |
| Delivery Weeks | 65 | 65 | 65 | 65 | 65 |

* Ionics costs do not reflect water tariff

Consolidated Water and Biwater were evaluated to have the lowest Bid Prices at and the lowest overall Evaluated Prices for the Base Bid. The Bid Price is essentially the price which WSC will pay to the successful Contractor for desalinated water delivered during the first year of operation of the plant. This price includes all costs except for the power cost per kigal and the Demand Charge, which will be paid by WSC. The Evaluated Bid Price includes the calculated costs to WSC for electricity and demand charge based on the Bidder's guaranteed power consumption and maximum kVA demand figures. The Evaluated Price represents the total direct costs to WSC associated with the production of desalinated water.

In addition to the base bids, the Bidders were allowed to offer alternate bids that could include innovations that could result in added value or cost savings to WSC. Examples of innovations included the use of diesel drives on the high pressure RO pumps, incorporation of a NRW reduction program, the shared use of seawater supply and disposal wells with the adjacent Blue Hills Power Station. The bid results for these alternate bids are summarized in the following table.

| BID DATA | CONSOLIDATED | BIWATER | IONICS* | IDE | ENERSERVE |
|---|---|---|---|---|---|
| Bid Price (B$/kigal) | $3.399 | $2.741 | $3.197 | - | $4.198 |
| Evaluated Price (B$/kigal) | $3.926 | $4.279 | $4.987 | - | $6.787 |
| Capital Cost (B$1000) | $19,612 | $17,804 | $29,700 | - | $45,305 |
| Delivery Weeks | 65 | 65 | 52 | - | 65 |

* Ionics costs do not reflect water tariff

Again, Consolidated Water and Biwater had the lowest overall Evaluated Prices for the 4 migd Alternate Bid. Consolidated's Alternate Bid is based on installing diesel drives on the high pressure RO pumps similar to the Windsor Reverse Osmosis Plant. Because Consolidated's alternate bid price includes the cost of diesel fuel for the high pressure RO pumps while the others do not, Consolidated's bid price does not appear to be in the lowest two bids. However, when all costs were considered, Consolidated's overall evaluated price was one of the two lowest bids. The Biwater alternate proposal included a NRW reduction program with a guarantee for reducing NRW by 1 migd within one year after contract award. The Biwater offer also proposed using integrated use of the seawater supply and disposal wells between the desalination plant and the Blue Hills power station. In evaluation of these proposals the cost benefits of the diesel driven option had to be compared against the potential costs savings of the NRW reduction program. At the same time commercial and technical issues had to be evaluated concerning the use of the supply and disposal wells owned by the Bahamas Electricity Corporation (BEC).

## Sensitivity Analysis of Power Cost

In evaluating the bids, the cost of energy is typically a major component in the cost of water for a seawater reverse osmosis plant. The cost of electricity in the Bahamas is relatively high at $0.1285/kwh. As a result of this higher electricity cost, the cost of power represents approximately 36 percent of the total cost of water for the Blue Hills Desalination Plant base bids. To reduce the overall cost of water for the Windsor Project, Waterfields used diesel drives instead of electric motor drives for the high pressure membrane feed pumps. Consolidated proposed a similar scheme for the Blue Hills Desalination Plant as an alternate bid. A comparison of the diesel driven alternate bid to the electric motor driven base bid is provided in **Figure 1**. This figure illustrates the sensitivity of the cost of water to the cost of electricity. As the cost of power is decreased from the large industrial user rate of $0.1285/kwh, the electric motor driven option becomes more competitive and becomes the most cost effective solution for a power cost of $0.08/kwh or lower. Reducing the power cost from $0.1285 to $0.08/kwh would also result in a reduction in the overall cost of water from $4.40/kigal to approximately $3.75/kigal for the base electric driven alternative.

For the diesel driven alternate, only the high pressure membrane feed pumps are diesel driven and the balance of plant loads are motor driven, so the cost of the diesel driven option also tends to decrease with decreasing electricity rates. The sensitivity analysis in **Figure 1** demonstrates that the diesel driven option is the most cost effective alternative, unless WSC could negotiate a lower tariff for electricity with the Bahamas Electricity Corporation (BEC). The new seawater reverse osmosis plant would provide a major base loaded, new power customer directly adjacent to BEC's Blue Hills Power Station. Considering the size of this account and proximity to the power station and the lower transmission and administrative costs to service this facility, it was anticipated that there would be an incentive to lower the electricity tariff for this project. While the Government did authorize a lower electricity tariff for this facility for the first two years of operation, it was later decided to select the diesel driven alternative.

## Reducing the Cost of Water

The two lowest bids received by WSC offered water costs of less than $4.00/kigal when the alternate bids including the value of reducing NRW were considered. These bids represented a significant cost savings over the original contract price of $5.75/kigal for the Windsor Desalination Plant. A comparison of the unit cost of water for the Windsor Seawater RO Plant with the bids received for the Blue Hills Seawater RO Plant is summarized in **Table 2**. One of the largest overall cost reductions was in the capital cost component which was reduced from $2.103 to $1.382/kigal. The Windsor facility is a two pass design and it is estimated that elimination of the second pass would reduce the overall cost from $2.103 to approximately $1.91. Interest rates in 1995 when the Windsor project was bid were higher than the current rates. The interest rate used for financing the Windsor Plant was 12 percent. For the Blue Hills bids financing rates of less than 7 percent were offered. The impact of lowering the interest rate for financing from 12 percent to an average rate of 8 percent represents an approximate savings of $0.44/kigal in the cost of water. In addition increasing the term of the contract from 15 years to 20 years tends to reduce the cost of water by almost $0.20/kigal. Economy of scale for the larger Blue Hills facility also helps to reduce the capital cost component of the project and tends to offset increases in construction costs that have occurred between 1995 and the present.

Other areas of significant cost savings are in administrative and labor costs for the project. The total costs for administration and labor for a 6 migd facility are only marginally higher than for a 2 migd facility, so the unit costs would be expected to be approximately three times lower as reflected in the bid prices. In addition, some reduction in labor and administrative costs could be expected for a facility with all electric motors drives as compared to the diesel driven concept at Windsor.

There have been significant improvements in membrane technology since the Windsor plant was installed. Membrane rejection has increased from 99.5 percent to over 99.7 percent, which means that the product TDS would be approximately 50 percent lower. In addition, improvements in specific flux reduced operating pressure from 1000 psi to 800 to 850 psi for some bids. Despite these improvements, the current high cost of fuel and high power costs tend to mask savings associated with power consumption. Also, the Windsor plant was a highly efficient design which included 92 percent efficiency positive displacement membrane feed pumps and 93 percent efficiency work exchangers. The larger size of the membrane treatment units for the Blue Hills design makes the use of positive displacement pumps impractical. Although multistage centrifugal pumps in this size range have efficiencies of only 80 to 82 percent, it was considered that the improved reliability and lower maintenance for the centrifugal pumps would result in a higher online factor which would more than compensate for the lower efficiency. However, the actual online factor of the positive displacement pumps is not reflected in the bid figures, the lower efficiency of the centrifugal pumps partially masks improvements in the membrane technology. It is estimated that the specific energy consumption for the Windsor plant without the second pass would be approximately 13 kwh/kigal. Energy consumption offered by the bidders for the Blue Hills plant were in the range of 11 to 13 kwh/kigal, so despite the lower pump efficiency, some overall performance efficiency was still realized.

Chemical costs are higher for the Blue Hills plant due to the post-treatment requirements for passivation of the permeate. In the Windsor plant, the permeate was blended with and equal quantity of groundwater and no post-treatment was required. Due to the larger size of the Blue Hills facility and limitations on groundwater availability, similar blending is not an option for this project. Instead the permeate will be treated with lime or calcite, carbonation and chlorination.

Operational cost savings were offered on membrane replacement, spare parts, and cartridge filters and consumables, and the overhead and profit on consumables.

### Non-Revenue Water Program

A unique feature of the Biwater proposal was the inclusion of a Non-Revenue Water (NRW) Reduction Program. As discussed above, WSC is well aware of the potential benefits associated with a NRW reduction program and have been developing their own NRW reduction program for several years. Considerable thought was given to the evaluation of this NRW reduction feature. While the bidder proposed evaluating the cost savings on the additional revenue associated with an increase of 1 migd of water available for sale, it was concluded that reducing losses would not necessarily increase demand. Instead, it was considered more appropriate to evaluate the savings resulting from NRW reduction through the associated reduction in WSC's production costs. Since the more expensive water supply alternatives including the Windsor Seawater RO Contract and importing water from Andros are under long term contracts with penalties associated with early termination, it is not practical to terminate these contracts. The sources that could be most easily curtailed are the groundwater supplies. However, these supplies are also the lowest cost sources. **Table 1** summarizes the avoided production costs associated with reducing groundwater supplies by 1 migd as a result of corresponding reductions in NRW.

Another important aspect to consider was the fact that the NRW reduction proposal was contingent on WSC's implementation of repairs in a timely manner and within WSC's current NRW program budget constraints. In addition, consideration had to be given to the time period over which the avoided production costs should be credited. The NRW guarantee was a one time guarantee and WSC would be responsible for maintaining the 1 migd in NRW reduction after the guarantee was achieved. The evaluation had to consider whether its was appropriate for the bidder to receive credit for the avoided production costs associated with the 1 migd reduction in NRW over the entire contract period based on a guarantee which may be satisfied within the first year of operation. It was further recognized that the true advantage of the proposed NRW program would be the reduction in time and the associated avoided production costs that would be achieved with Biwater's NRW program over the time required for WSC's NRW program to achieve the same 1 migd reduction in NRW. Ultimately, WSC was in the best position to assess the potential savings of Biwater's NRW program compared to WSC's existing program. Biwater's proposed NRW program included guarantees which would provide compensation in the form of production of an equivalent volume of potable water to cover any shortfall in the quantity of NRW reduction actually achieved. This compensation provided additional assurance to WSC that the guarantee would actually be achieved.

## Conclusions

WSC received two very competitive bids for the Blue Hills Seawater Reverse Osmosis Plant. Both proposals included alternates that offered significant value to WSC and implementation of either proposal would have resulted in significant cost savings as compared to the current contract rates for desalinated water or the cost of the shipping program. The primary differences between these proposals were:

- Diesel versus electric driven high pressure RO pumps
- Non-Revenue Water Reduction Program including Performance Guarantees
- Integration of the seawater RO plant with the operation of cooling water supply and disposal wells of the BEC Blue Hills Power Station including use of warmer RO inlet temperatures.

The diesel driven RO option would result in savings of approximately $0.43/kigal or $606,000 per year for the 4 migd production rate. At an avoided production cost of $2.00/kigal, a 1.0 migd reduction in NRW would result in annual savings of $730,000 within 1 year after contract award. At that point in the program, WSC's staff would have received additional leak detection equipment and training, and each district in the distribution system would be metered with the data being collected by a new SCADA system. As a result, WSC should be in a better position to sustain or improve upon this reduction in NRW losses. Since current NRW losses are projected to be closer to 5 migd, there is a significant opportunity for further reductions in NRW losses beyond the 1 migd guarantee. For this reason, WSC was very interested in accelerating the NRW reduction program and devoted significant effort to developing the terms of the NRW Reduction Agreement and associated guarantees.

While Biwater's proposal for integrated use of the power station feed and disposal wells introduced some additional contractual complications, it offered advantages in avoided costs for additional supply and disposal wells and potential environmental advantages of overall reduced seawater withdrawals and concentrate rejection volumes. The

Biwater proposal also introduced impacts on the Form of Agreement for purchase of desalinated water associated with third party ownership of the feed and disposal wells for the project. In addition, this proposal required additional changes to the Form of Agreement that introduced some complications in concluding the negotiation process.

In the end, WSC awarded the contract to Consolidated on the basis of their diesel driven alternate bid. Consolidated included a NRW program which was considered to provide a stronger Performance Guarantee. Under this Performance Guarantee Consolidated will provide 1 migd of desalinated water at no cost to WSC from the first day after the commissioning date of the facility until the 1 migd NRW reduction is achieved. In this case, Consolidated proposed to install all 6 migd of production capacity in the initial facility. The installation of the sixth membrane unit will provide the 4 migd of guaranteed capacity together with the 1 migd of reserve capacity required in the specifications while providing an additional unit to provide the 1 migd of desalinated water until the 1 migd reduction in NRW is realized. The unit price for the 4 migd guaranteed quantity for this proposal was increased to reflect the higher capital recovery costs associated with the sixth membrane unit; however, when the additional NRW is considered, the overall price is still less than $4.00 per kigal ($3.33/1000 US gal). This price still represents a much lower cost than the cost of the current primary water supply, which is based on shipping water from Andros Island, and is the most cost effective solution for meeting the future water needs of Nassau.

| TABLE 1 | | | | |
|---|---|---|---|---|
| **IMPACT OF NRW REDUCTION ON PRODUCTION COSTS** | | | | |
| | | | | |
| **Current Operation** | | | | |
| **Source** | **Qty, MIGD** | **CostKIGAL** | **Cost/Day** | **Cost/Yr** |
| Barging | 4.8 | $5.50 | $26,400 | $9,636,000 |
| Windsor | 2 | $6.70 | $13,400 | $4,891,000 |
| Groundwater | 2.5 | $2.00 | $5,000 | $1,825,000 |
| Other | 0 | $5.00 | $0 | $0 |
| Total | 9.3 | | $44,800 | $16,352,000 |
| Average | | $4.82 | $4,817 | |
| Loss Percentage | 50.0% | | | |
| Quantity Delivered | 4.65 | | | |
| Qty Lost, Migd | 4.65 | | | |
| Total Unit Production Cost | | | | $4.82 |
| | | | | |
| NRW Program (1 MIGD NWR Reduction) | | | | |
| Source | Qty, MIGD | CostKIGAL | Cost/Day | Cost/Yr |
| Barging | 1.8 | $5.50 | $9,900 | $3,613,500 |
| Windsor | 2 | $6.70 | $13,400 | $4,891,000 |
| Groundwater | 0.5 | $2.00 | $1,000 | $365,000 |
| Blue Hills | 4 | $3.93 | $15,720 | $5,737,800 |
| Total | 8.3 | | $40,020 | $14,607,300 |
| Average | | $4.82 | $4,822 | |
| Loss Percentage | 44.0% | | | |
| Quantity Delivered | 4.65 | | | |
| Qty Lost, Migd | 3.65 | | | |
| Total Production Cost Savings | | | | $1,744,700 |
| Total Unit Production Cost | | | | $4.82 |
| Production Cost Savings for 1 MIGD Reduction in NRW | | | | $730,000 |
| Unit Cost Savings | | | | $2.00 |

**TABLE 2**
**COST OF WATER COMPARISON - BLUE HILLS vs WINDSOR**

| Project | Blue Hills | Windsor | Difference |
|---|---|---|---|
| Company | **Composite** | | |
| Installed Capacity, IGPD | 6,000,000 | 2,200,000 | |
| Plant Production Rate, IGPD | 5,000,000 | 2,000,000 | |
| Annual Prod. kgal/yr | 1,825,000 | 730,000 | |
| Annual Interest Rate | 6.2%-12.0% | 12.00% | |
| Number of Years | 20 | 15 | |
| Availability Factor | 100.00% | 90.91% | |
| Plant Capital Cost | $25,200,000 | $10,658,000 | |
| Plant Capital Cost | **$4.200** | **$4.360** | |
| Production Costs (Annual) | | | |
| **FIXED COSTS** | | | |
| Fixed Charges - Capital Repayment | 1.382 | 2.103 | 0.721 |
| General & Administrative (Note 1) | 0.281 | 1.012 | 0.731 |
| Operation & Maintenance Labor | 0.229 | 0.374 | 0.145 |
| Overhead & Profit on Labor | 0.037 | 0.094 | 0.057 |
| SUSTOTAL FIXED COSTS | **1.929** | **3.583** | 1.654 |
| Note 1: includes allowance for bonding and insurance | | | |
| Equivalent Power Consumption, kwh/kigal | 11.770 | 13.000 | |
| **CONSUMABLES** | | | |
| **Diesel Fuel** | **0.735** | **0.596** | **(0.139)** |
| **Electricity** | | | |
| Power Consumption | **0.436** | **0.395** | **(0.041)** |
| | | | |
| Demand Charge | **0.062** | **0.052** | **(0.010)** |
| | | | |
| Chemicals | 0.265 | 0.048 | (0.217) |
| Spare Parts | 0.118 | 0.185 | 0.067 |
| Replacement Membranes | 0.109 | 0.346 | 0.237 |
| Cartridge Filters & Misc Consumables | 0.046 | 0.112 | 0.066 |
| Other | 0.008 | - | (0.008) |
| Subtotal Consumables-less Profit | 0.546 | 0.691 | 0.145 |
| Overhead & Profit on Consumables | 0.110 | 0.386 | 0.276 |
| SUBTOTAL CONSUMABLES | 0.656 | 1.077 | 0.421 |
| TOTAL BID PRICE: | **3.818** | **5.703** | **1.885** |

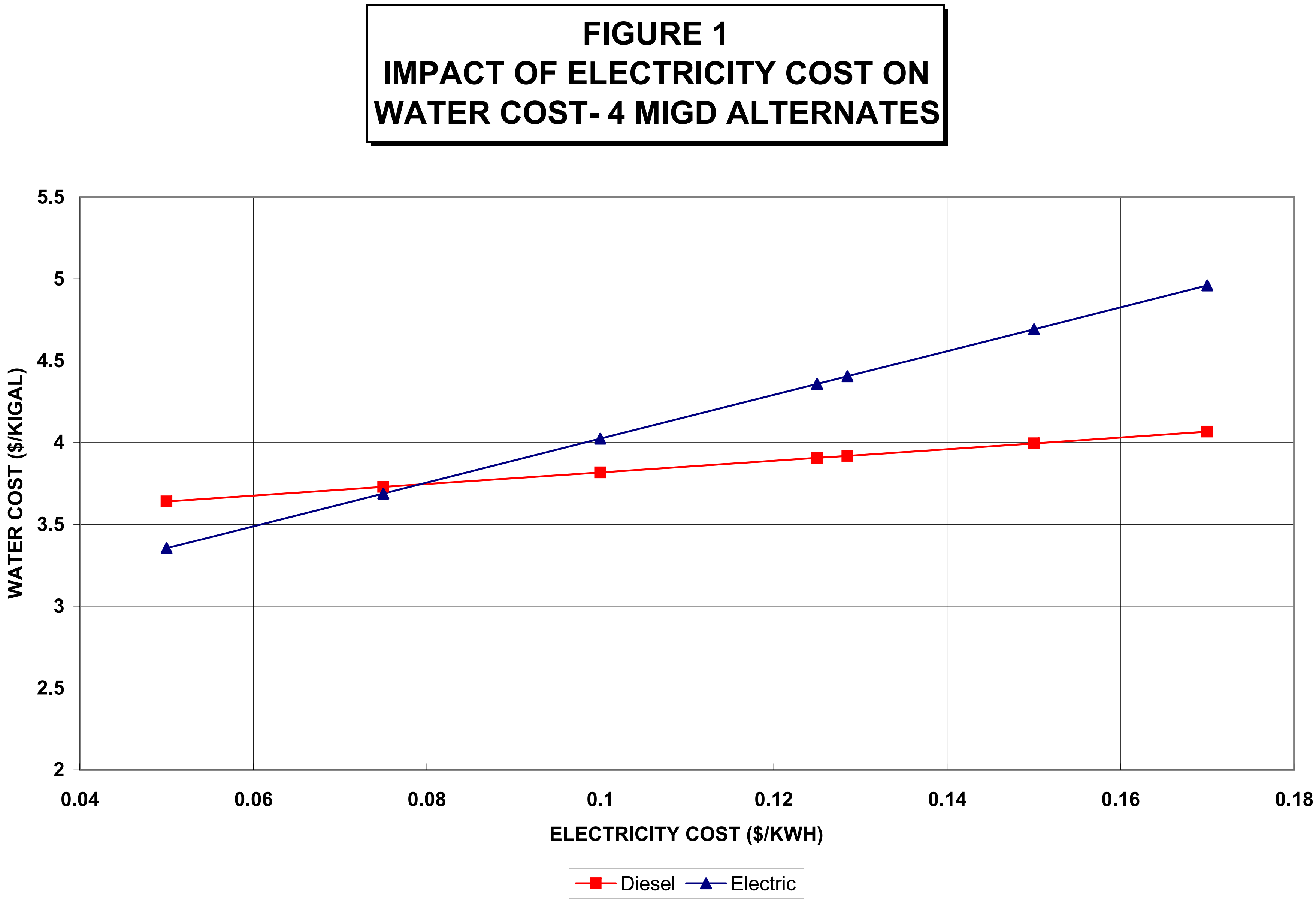
FIGURE 1
IMPACT OF ELECTRICITY COST ON
WATER COST- 4 MIGD ALTERNATES
5.5
5
4.5
4
3.5
3
2.5
2
WATER COST ($/KIGAL)
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
ELECTRICITY COST ($/KWH)
Diesel
Electric