June 4, 2014

City of Bend
575 N.E. 15th Street
Bend, OR 97701

Attention: Tom Hickmann, P.E.
EIPD Director

RE: Carbon Footprint of Water Supply Alternatives

Dear Mr. Hickmann,

The City of Bend has two water sources: gravity flowing surface water and pumped groundwater. This letter estimates the potential power consumption and operating greenhouse gas (carbon footprint) equivalencies if the City were to replace its existing gravity flow surface water supply with water pumped out of the ground.

Methods. The governing equations for pumping power and energy are:

P = Q * H / n / C where: P = power in kilowatts; Q = flow (gallons per minute); H = Head in feet; n = efficiency; C is a conversion constant 5310.4

E = P * t where E = energy in kW-hr, and t is pumping time in hours

Water Use. Average monthly water use was calculated from year 2013 daily City records and used to represent present conditions. Maximum flow conditions were also evaluated assumed to be uniform at 18.2 cfs or 11.76 mgd, the anticipated capacity limit by federal permit.

Groundwater. Potential depth to groundwater was estimated as the average of existing groundwater wells (static water level 482-feet below ground), documented in Optimatics reference Table 3.7. The following assumptions were made that cause an underestimate of power consumption and carbon footprint: there is no drawdown of water level with pump operation and the need to boost water to higher elevation pressure zones is neglected. It is assumed that the groundwater wells would need to discharge to pressurized piping at 80 psi (185 feet), yielding a total pumping head of 667 feet. Combined motor and pump efficiency is assumed to be 80%. Power and energy consumption estimates for pumped groundwater production are presented in Table 1.

Surface Water. With installation of membrane filters, surface water will also need to be pumped in the future. Assumed water use is the same as groundwater, as described above, to facilitate the power and energy comparison. The pumping head is lower for surface water and varies with flow rate. Receiving reservoirs are assumed to be half full.

Surface water enters the distribution piping system much higher than most City groundwater wells, but the energy benefit of not having to pump surface water within the distribution system is neglected. Power and energy consumption estimates for surface water production are presented in Table 2.

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Results. Estimates of power and energy consumption for present, future, and maximum flow conditions are shown in Table 1 for groundwater and Table 2 for surface water. A summary of results follows:

Summary energy use estimates (megawatt hours per year) (see Tables 1 and 2 for details)

Condition	Groundwater	Surface Water	Net Difference
Present	6,241	492	5,749
Maximum Flow	11,260	1,378	9,882

These estimates indicate that it is more energy intensive to obtain the water from deep groundwater wells rather than the existing elevated surface water source. The remainder of this letter addresses the greenhouse gas equivalencies associated with switching to the more energy intensive deep well water source.

The greenhouse gas equivalencies, expressed in Metric Ton Carbon Dioxide equivalent ($MTCO_2e$) of the additional energy that would be expended to obtain the water from pumped groundwater sources are estimated below:

- Present conditions additional carbon dioxide: 2,147 $MTCO_2e$ / year
- Maximum flow conditions additional carbon dioxide: 3,691 $MTCO_2e$ / year

Greenhouse gas emissions are expressed in $MTCO_2e$. The conversion of megawatt hours to $MTCO_2e$ was based on the standard emissions calculation methodology for electricity from the GHG Protocol, and covers the three main greenhouse gases associated with electricity consumption used in standard greenhouse gas accounting practices: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Electricity emissions data comes from the EPA's eGRID (US EPA Emissions & Generation Resource Integrated Database) program. Emissions factors for electricity varies by area due to regional differences in fuel sources for power plants. The emissions factors for CO_2, CH_4 and N_2O (for the WECC Northwest subregion) were obtained from the eGRID version 1.0, Year 2010 Summary Tables.

Emissions Factors

Greenhouse Gas	CO_2	CH_4	N_20
Emissions Factor (lbs/MWh)	842.58	16.05	13.07

The formula for calculating greenhouse gas emissions is:

Activity data x emission factor = emissions

Annual Emissions in $MTCO_2e$ / year

Greenhouse Gas	CO_2	CH_4	N_20	Total $MTCO_2e$
Present Conditions (5,749 MWh/year)	2,136.3	0.8	10.1	2,147.2
Maximum Flow Conditions (9,882 MWh/year)	3,672.0	1.4	17.4	3,690.8

To put this in perspective, 3,691 $MTCO_2e$ is equivalent to the following:

- Annual GHG emissions from 777 average-sized passenger vehicles.
- Annual GHG emissions from 1,323 tons of waste sent to the landfill.
- GHG emissions from 415,303 gallons of gasoline consumed.
- GHG emissions from the *electricity* use of 508 homes for one year.
- GHG emissions from 153,783 propane cylinders used for home barbeques.

We appreciate the opportunity to evaluate this on behalf of the City. Please call if there are any questions regarding this matter.

Sincerely,

HDR Engineering, Inc.

Bryan Black, P.E.
Professional Associate, Vice President

Jeannie Renné-Malone, LEED AP BD+C, ENV SP, GGP
Director, Greenhouse Gas Management Services

References:

Optimatics, Water System Master Plan Update Optimization Study, Design Data Summary Report Final March 2010

HDR, Technical Memorandum: Surface Water / Groundwater Cost Comparison, October 27, 2010

GHG Protocol: http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf

USEPA eGRID: http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf

USEPA Greenhouse Gas Equivalencies Calculator: http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Table 1. Power and Energy Consumption Estimates for Additional Groundwater Production

1a) Present Conditions (2013)

Month	Avg Flow (mgd)	Avg Flow (gpm)	Head (ft)	Efficiency	Horsepower	KW	# of Hours/day operating	# of days operating	KW hr
Jan	4.6	3205	667	80%	675	503	24	31	374,365
Feb	4.5	3116	667	80%	656	489	24	28	328,702
Mar	4.4	3083	667	80%	649	484	24	31	360,150
Apr	5.6	3871	667	80%	815	608	24	30	437,608
May	4.7	3243	667	80%	683	509	24	31	378,808
Jun	10.6	7383	667	80%	1554	1159	24	30	834,592
Jul	10.9	7549	667	80%	1589	1185	24	31	881,767
Aug	10.9	7574	667	80%	1595	1189	24	31	884,674
Sep	9.9	6875	667	80%	1448	1079	24	30	777,213
Oct	4.6	3193	667	80%	672	501	24	31	372,992
Nov	2.7	1906	667	80%	401	299	24	30	215,403
Dec	4.9	3377	667	80%	711	530	24	31	394,411
								Total	6,240,685

1b) Maximum Flow Conditions

Month	Avg Flow (mgd)	Avg Flow (gpm)	Head (ft)	Efficiency	Horsepower	KW	# of Hours/day operating	# of days operating	KW hr
Jan	11.8	8187	667	80%	1724	1285	24	31	956,330
Feb	11.8	8187	667	80%	1724	1285	24	28	863,782
Mar	11.8	8187	667	80%	1724	1285	24	31	956,330
Apr	11.8	8187	667	80%	1724	1285	24	30	925,481
May	11.8	8187	667	80%	1724	1285	24	31	956,330
Jun	11.8	8187	667	80%	1724	1285	24	30	925,481
Jul	11.8	8187	667	80%	1724	1285	24	31	956,330
Aug	11.8	8187	667	80%	1724	1285	24	31	956,330
Sep	11.8	8187	667	80%	1724	1285	24	30	925,481
Oct	11.8	8187	667	80%	1724	1285	24	31	956,330
Nov	11.8	8187	667	80%	1724	1285	24	30	925,481
Dec	11.8	8187	667	80%	1724	1285	24	31	956,330
								Total	11,260,014

Table 2. Power and Energy Consumption Estimates for Surface Water Production

2a) Present Conditions (2013)

Month	Avg Flow (mgd)	Avg Flow (gpm)	Head (ft)	Efficiency	Horsepower	KW	# of Hours/day operating	# of days operating	KW hr
Jan	4.6	3205	32	80%	33	24	24	31	18,129
Feb	4.5	3116	32	80%	31	23	24	28	15,721
Mar	4.4	3083	32	80%	31	23	24	31	17,009
Apr	5.6	3871	37	80%	45	34	24	30	24,406
May	4.7	3243	33	80%	33	25	24	31	18,571
Jun	10.6	7383	70	80%	162	121	24	30	87,088
Jul	10.9	7549	72	80%	172	128	24	31	95,183
Aug	10.9	7574	72	80%	172	128	24	31	95,497
Sep	9.9	6875	64	80%	138	103	24	30	74,342
Oct	4.6	3193	32	80%	33	24	24	31	18,062
Nov	2.7	1906	26	80%	16	12	24	30	8,332
Dec	4.9	3377	34	80%	36	27	24	31	19,809
								Total	492,149

2b) Maximum Flow Conditions

Month	Avg Flow (mgd)	Avg Flow (gpm)	Head (ft)	Efficiency	Horsepower	KW	# of Hours/day operating	# of days operating	KW hr
Jan	11.8	8187	82	80%	211	157	24	31	116,996
Feb	11.8	8187	82	80%	211	157	24	28	105,674
Mar	11.8	8187	82	80%	211	157	24	31	116,996
Apr	11.8	8187	82	80%	211	157	24	30	113,222
May	11.8	8187	82	80%	211	157	24	31	116,996
Jun	11.8	8187	82	80%	211	157	24	30	113,222
Jul	11.8	8187	82	80%	211	157	24	31	116,996
Aug	11.8	8187	82	80%	211	157	24	31	116,996
Sep	11.8	8187	82	80%	211	157	24	30	113,222
Oct	11.8	8187	82	80%	211	157	24	31	116,996
Nov	11.8	8187	82	80%	211	157	24	30	113,222
Dec	11.8	8187	82	80%	211	157	24	31	116,996
								Total	1,377,537