Challenges with the Integration of Large Scale Wind by a Regional Utility

Wind Forecasting
And
System Operations

American Wind Energy Association

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Project Manager

Bonneville Power Administration

June 6, 2006

Special Thanks

- American Wind Energy Association
- Department of Energy
- National Renewable Energy Labs
- California Independent System Operator


Columbia River Basin
Mica
Duncan
Hugh Keenleyside
Arrow
CANADA
U.S.
Kootenai R.
Pend Oreille R.
Flathead R.
Libby
Hungry Horse
Albeni Falls
Chief Joseph
Grand Coulee
Wells
Rocky Reach
Rock Is.
Wanapum
Priest Rapids
SEATTLE
SPOKANE
MISSOULA
Clearwater NF
Lower Monumental
Little Goose
Lower Granite
Dworshak
Clearwater
The Dalles
John Day
Bonneville
Ice Harbor
McNary
PORTLAND
Columbia R.
Hells Canyon
Oxbow
Brownlee
BOISE
Snake R.

BPA – A Regional Wholesale Power Provider

- Operates in five states in the Pacific NW
- Customers – Public Utilities, Investor Owned Utilities & Direct Service Industries
- 21,944 MW total capacity – 31 dams, 1 nuke, wind
- 19,321 MW 60 minute system peak
- 7,712 aMW annual generation
- 15,342 miles of transmission 1000 – 115 kV
- May manage 2500 + MW of wind by end of 2008

Presentation Overview

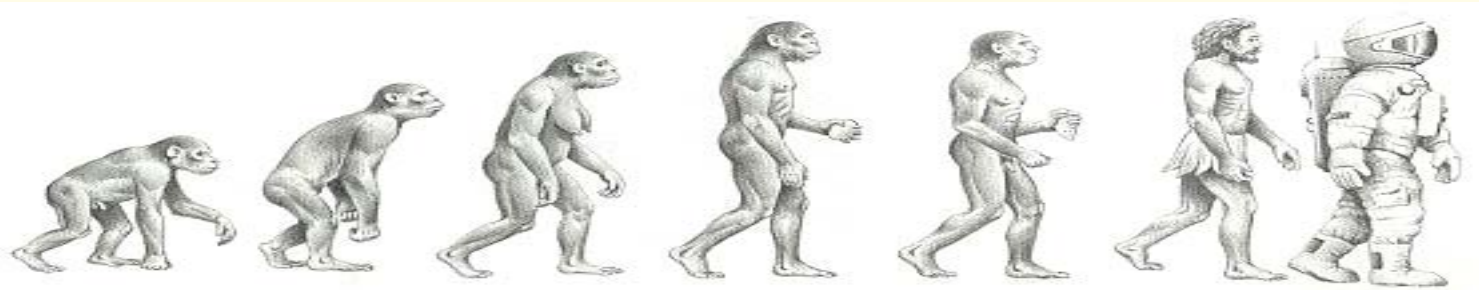
- BPA Wind Forecasting Network – goals
- Wind forecasting in the mid-Columbia Basin
- Planned expansion of wind at BPA
- Within the hour wind ramps – discussion
- Impact of large scale wind ramps on system operations – power and transmission
- Prototype RD&D within-the-hour forecast system

Generation and Transmission at BPA

- In 1996, BPA functionally separated into independent generation and transmission organizations
- BPA remained operationally integrated
- A regional Pacific NW transmission operator has not materialized
- Planned large scale wind development is poised to impact both business lines

Evolution of Wind at BPA

- **Responsibilities under the Power Act and FERC tariff to facilitate and integrate renewable energy**
- **1000 MW RFP (2001) – Region wakes up to wind**
- **1st wind/hydro integration study (2002) – Eric Hirst**
- **Innovative Wind Integration and Wind Storage & Shaping products (2004)**
  http://www.bpa.gov/power/pgc/wind/wind.shtml
- **PBL 208 MW – load serving and Storage & Shaping**
- **TBL 1650 MW+ – by 2008 for loads external to BPA**



BONNEVILLE POWER ADMINISTRATION

BPA Wind Forecasting Network

"Active Management of BPA (PBL) Wind"

- A Two-Year Wind/Hydro Optimization **RD&D** Project
- Supported by **DOE** & the National Renewable Energy Laboratory **(NREL)**
- Forecast wind each hour from **present time** to **seven days** into the future (**168 hours**)
- Improve the quality of wind generation forecasts for BPA's hydro optimization models **– Columbia Vista, NRTO**

Wind Forecasting Network cont.

- Improve quality of wind generation forecasts to **inform** near-term **marketing decisions** (increasing revenue)
- Establish operating impacts of **Wind Integration and Wind Storage and Shaping** products (reducing costs)
- **Determine** if wind has a **capacity value** (increasing revenue) and the **capacity needed** to **support its uncertainty** (reducing costs), given an accurate wind forecast
- Project **may evolve** to **actively manage within-the hour wind**

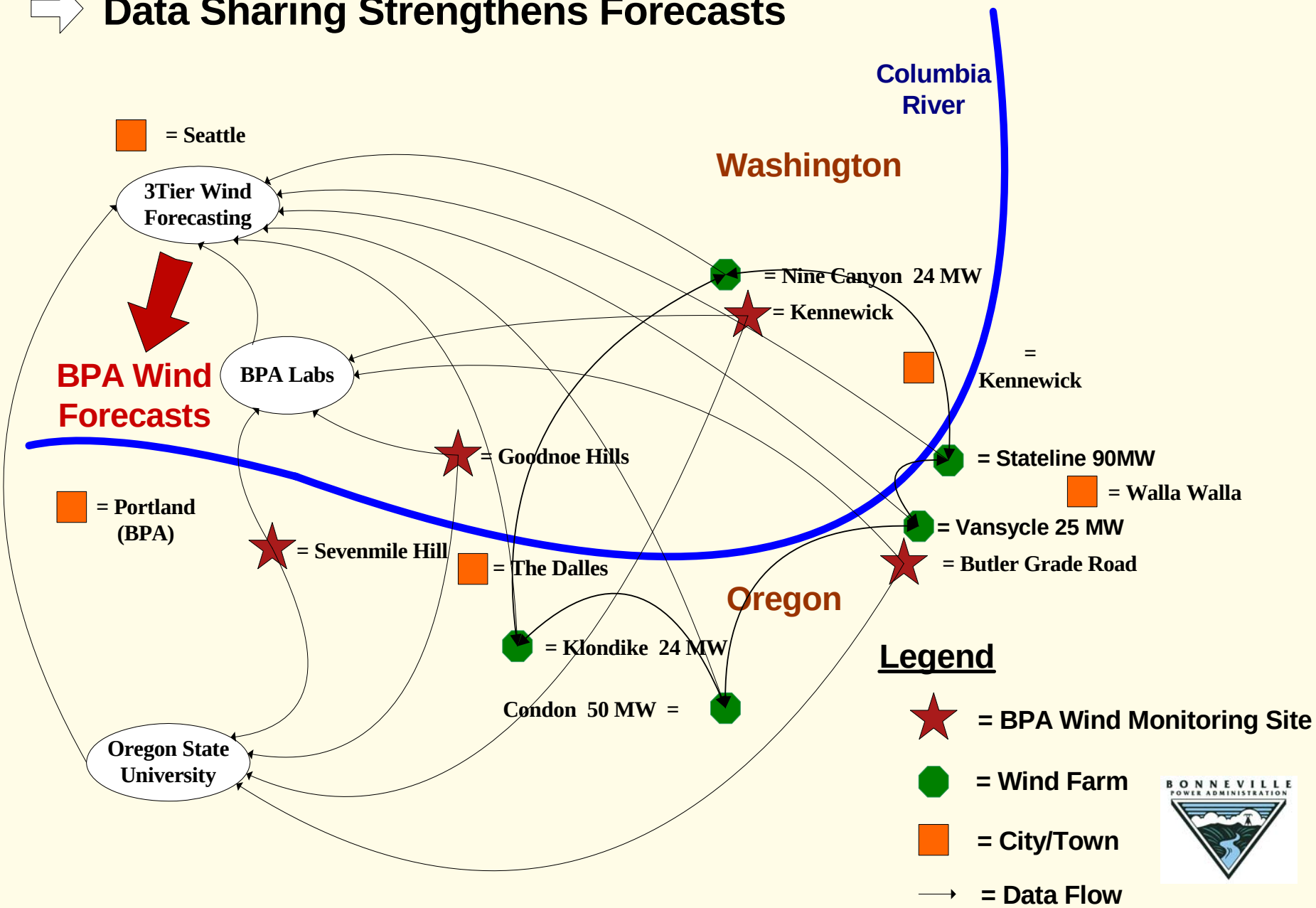
Building the Forecasting Network

- Honeymoon with wind – Long gone!
- Wind plant owner/operators unwilling to share information – perceived FOIA threat
- Innovative data sharing arrangement negotiated
- All on-site data (wind/power) given to 3rd party – 3TIER, who forecasts for each
- Data sharing strengthens forecasts for all

BPA Wind Forecasting Network

8/27/04

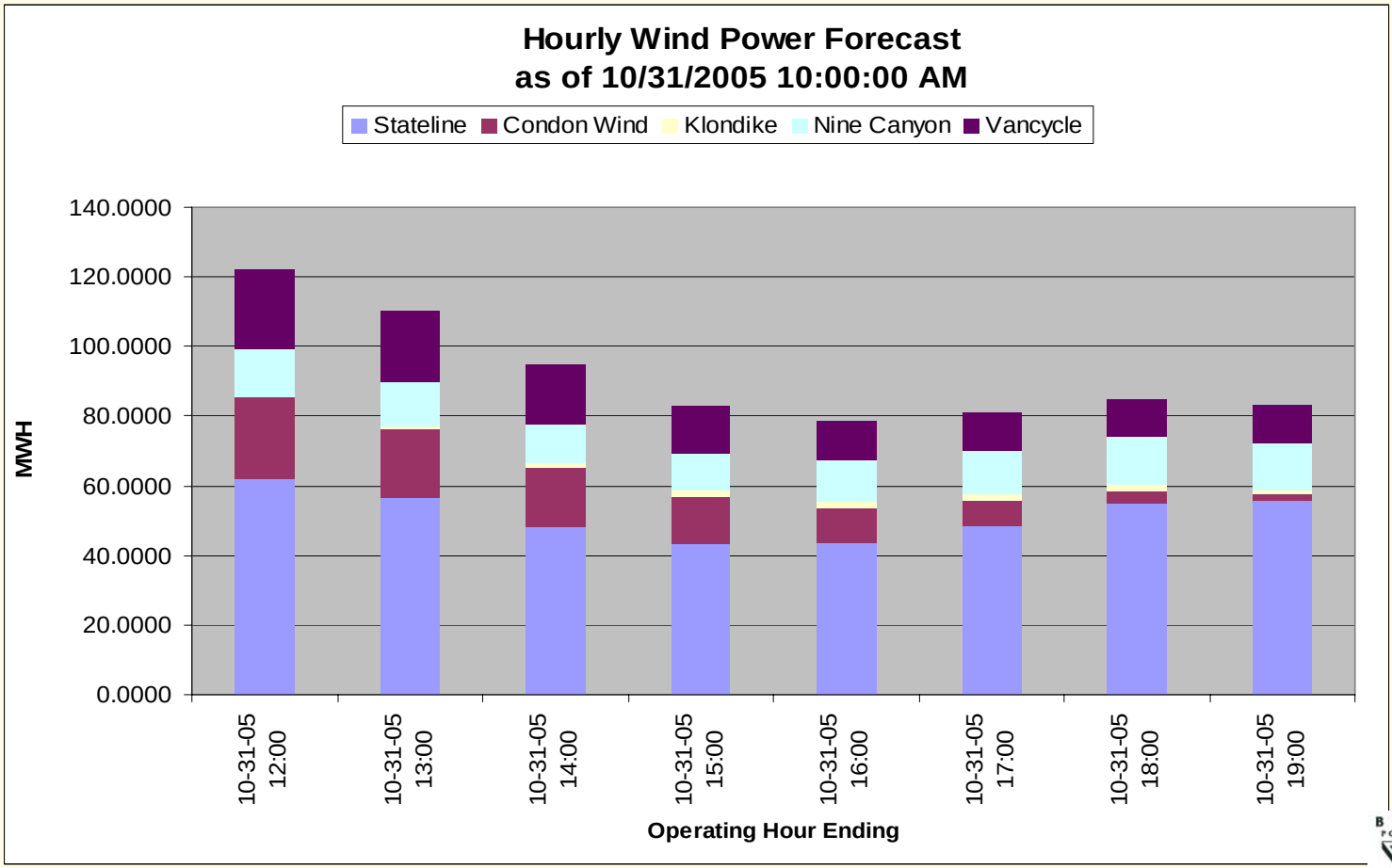
Data Sharing Strengthens Forecasts



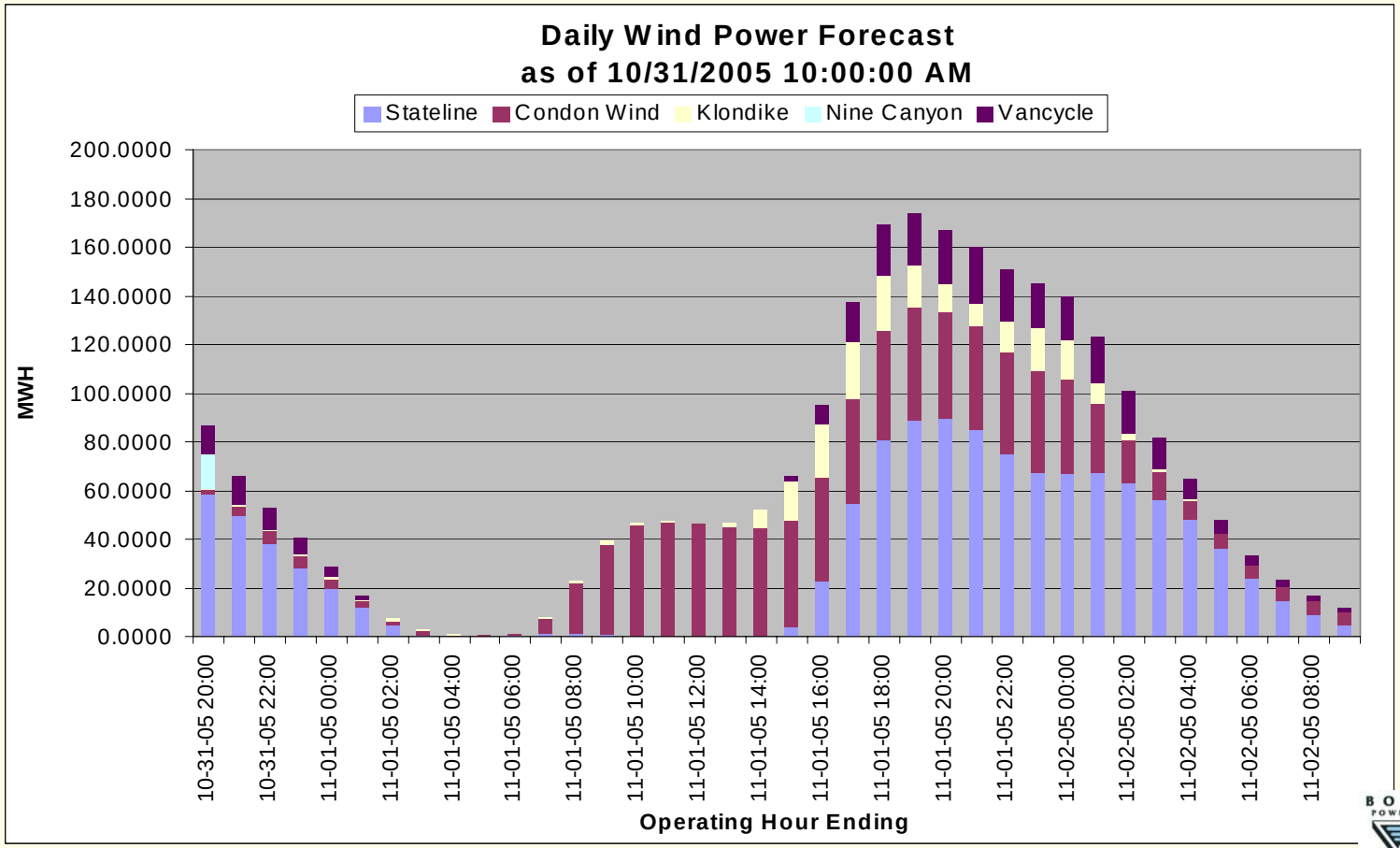
Wind Forecasts 24/7 – 365

- ***"Hour ahead" forecast:*** For the **next 8 operating** hours forecasts will be made and **updated every 10 minutes.**
- ***"Day ahead" forecast:*** For the **next 60 hours** forecasts will be **updated** at least 3 times daily at **3 a.m., at 10 a.m. and at 3 p.m.**
- ***"Week ahead" forecast:*** For the **next 100 hours**, forecasts will be provided and updated once daily by **6 a.m.**
- ***"Next week" forecast:*** The **historical average** of wind plant output each hour after hour **168 to 336** (2nd week).

Hourly Wind Forecast
Every 10 Minutes – next 8 hours

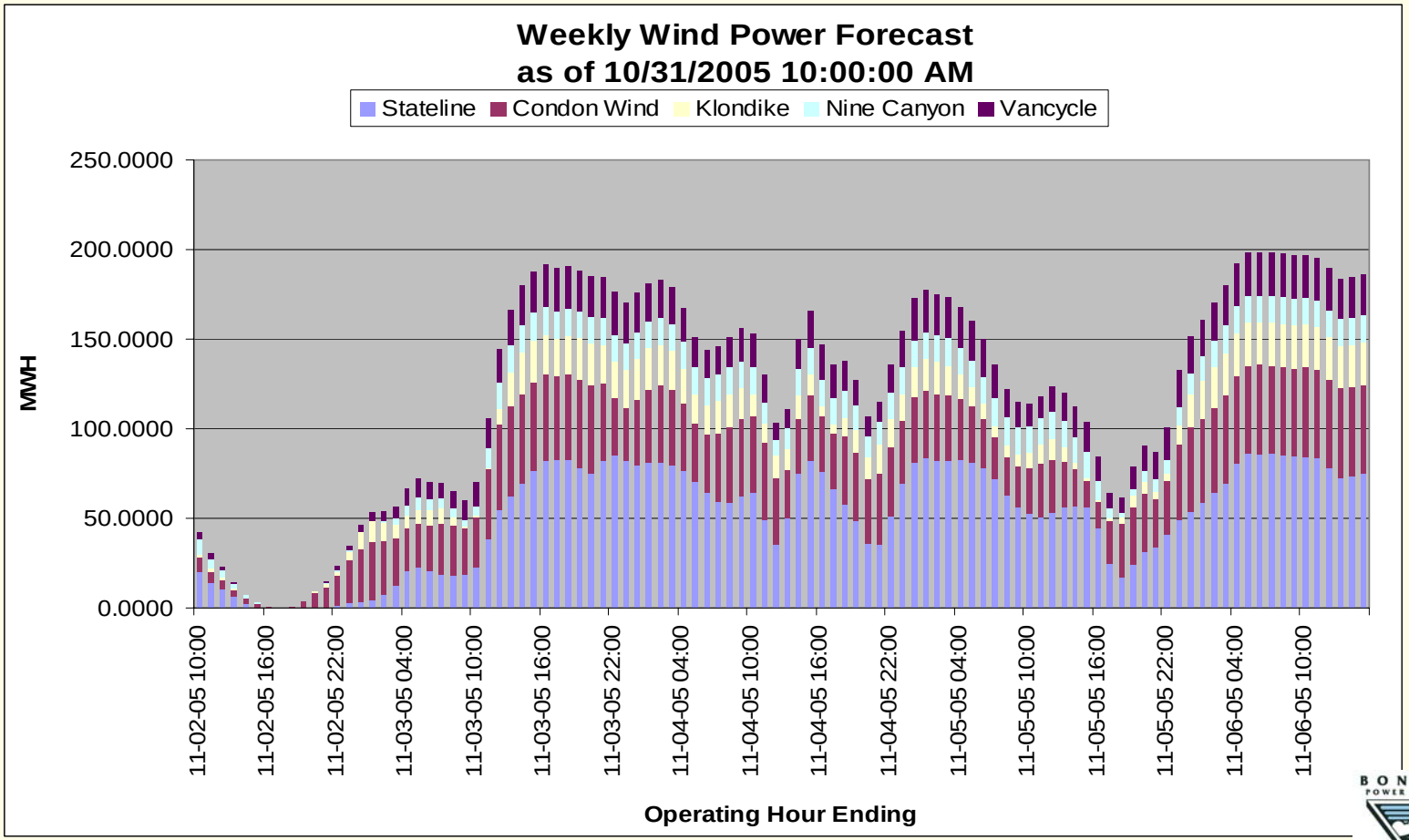


Daily Wind Forecast
Three Times Daily – 2 ½ days



BONNEVILLE POWER ADMINISTRATION

Weekly Wind Forecast
Once a Day – This Week

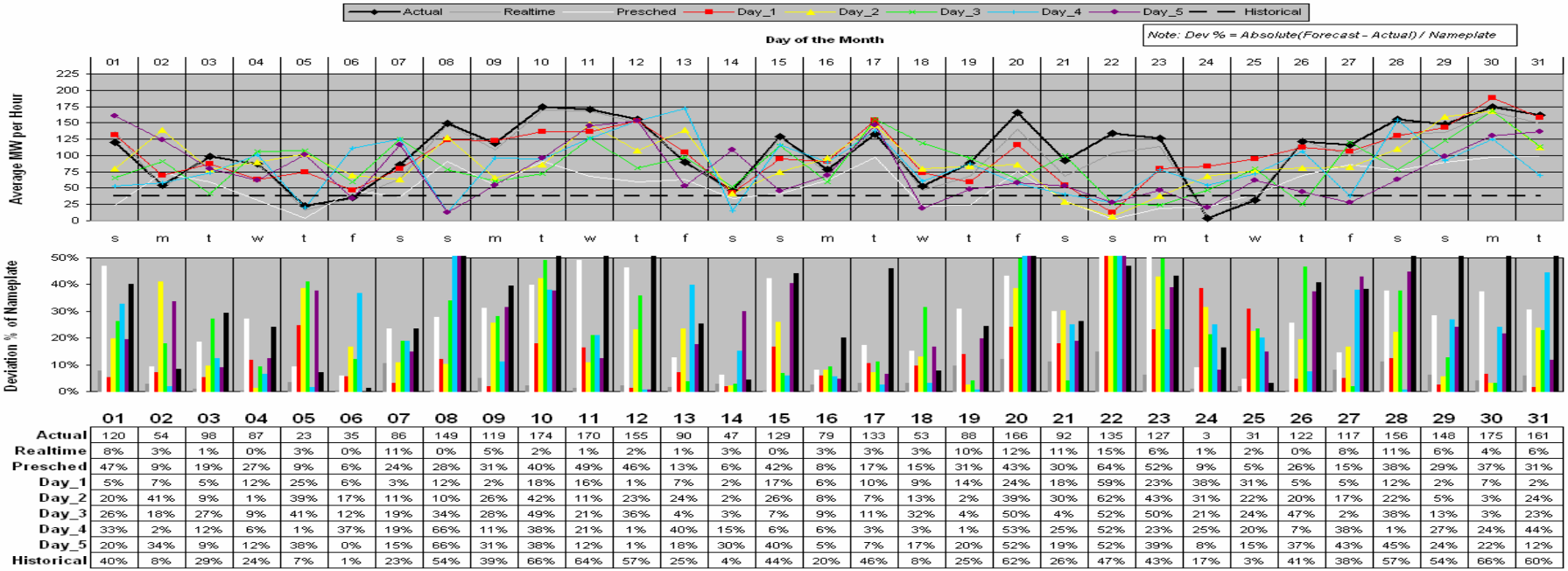


Monthly Forecast Results

please see next slide

January 2006 Wind Power Forecasts to Actuals

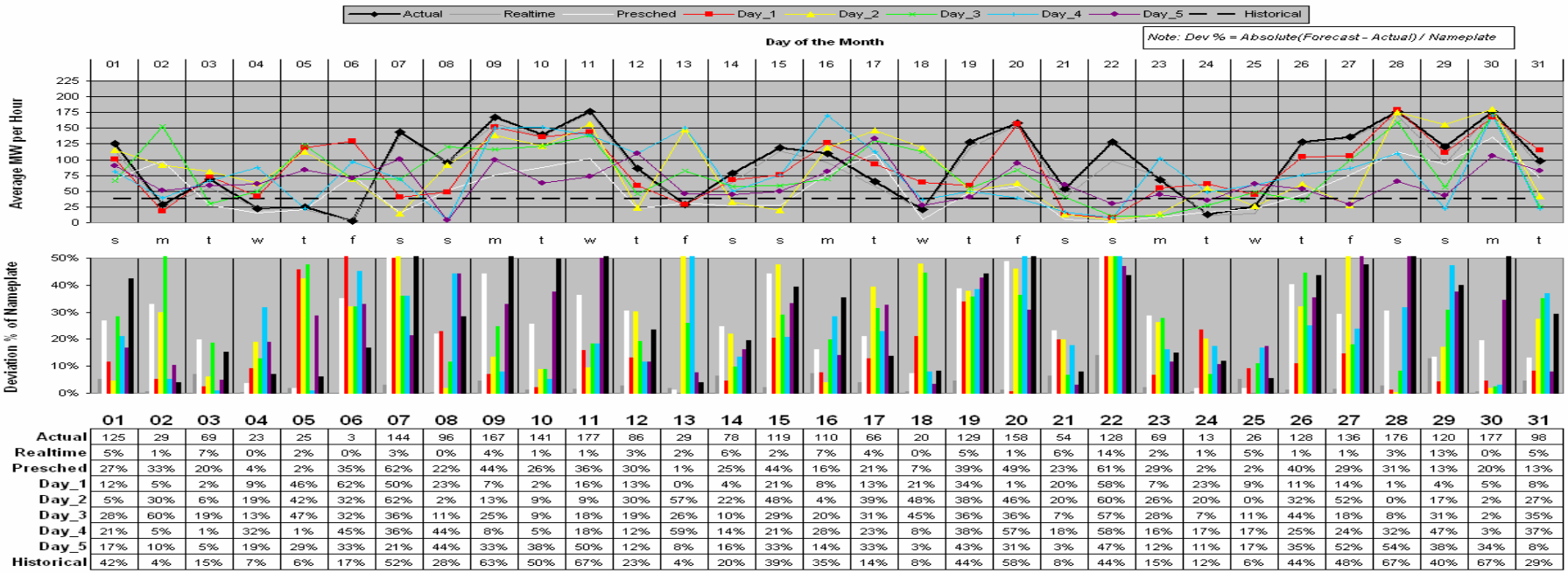
Light Load (10PM to 6AM)



	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Actual	120	54	98	87	23	35	86	149	119	174	170	155	90	47	129	79	133	53	88	166	92	135	127	3	31	122	117	156	148	175	161	Avg
Realtime	8%	3%	1%	0%	3%	0%	11%	0%	5%	2%	1%	2%	1%	3%	0%	3%	3%	3%	10%	12%	11%	15%	6%	1%	2%	0%	8%	11%	6%	4%	6%	5%
Presched	47%	9%	19%	27%	9%	6%	24%	28%	31%	40%	49%	46%	13%	6%	42%	8%	17%	15%	31%	43%	30%	64%	52%	9%	5%	26%	15%	38%	29%	37%	31%	27%
Day_1	5%	7%	5%	12%	25%	6%	3%	12%	2%	18%	16%	1%	7%	2%	17%	6%	10%	9%	14%	24%	18%	59%	23%	38%	31%	5%	5%	12%	2%	7%	2%	13%
Day_2	20%	41%	9%	1%	39%	17%	11%	10%	26%	42%	11%	23%	24%	2%	26%	8%	7%	13%	2%	39%	30%	62%	43%	31%	22%	20%	17%	22%	5%	3%	24%	21%
Day_3	26%	18%	27%	9%	41%	12%	19%	34%	28%	49%	21%	36%	4%	3%	7%	9%	11%	32%	4%	50%	4%	52%	50%	21%	24%	47%	2%	38%	13%	3%	23%	23%
Day_4	33%	2%	12%	6%	1%	37%	19%	66%	11%	38%	21%	1%	40%	15%	6%	6%	3%	3%	1%	53%	25%	52%	23%	25%	20%	7%	38%	1%	27%	24%	44%	21%
Day_5	20%	34%	9%	12%	38%	0%	15%	66%	31%	38%	12%	1%	18%	30%	40%	5%	7%	17%	20%	52%	19%	52%	39%	8%	15%	37%	43%	45%	24%	22%	12%	25%
Historical	40%	8%	29%	24%	7%	1%	23%	54%	39%	66%	64%	57%	25%	4%	44%	20%	46%	8%	25%	62%	26%	47%	43%	17%	3%	41%	38%	57%	54%	66%	60%	35%

January 2006 Wind Power Forecasts to Actuals

Heavy Load (6AM to 10PM)



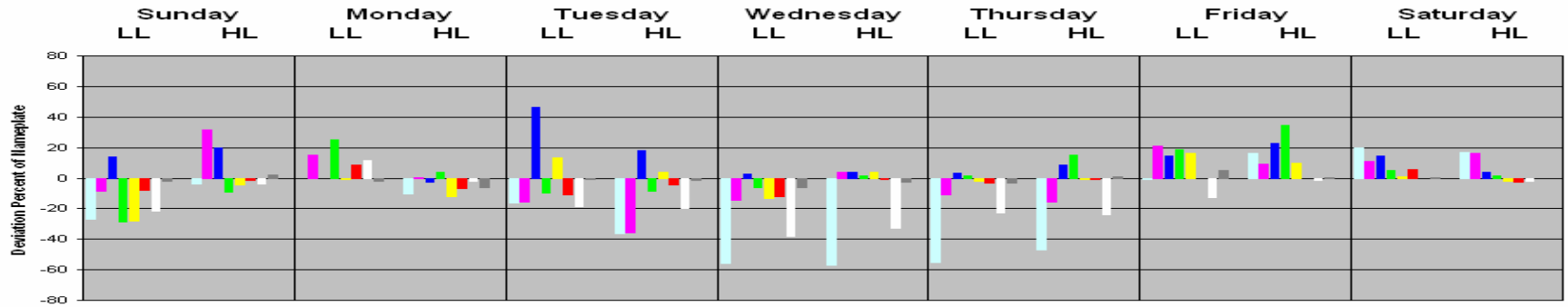
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Actual	125	29	69	23	25	3	144	96	167	141	177	86	29	78	119	110	66	20	129	158	54	128	69	13	26	128	136	176	120	177	98	Avg
Realtime	5%	1%	7%	0%	2%	0%	3%	0%	4%	1%	1%	3%	2%	6%	2%	7%	4%	0%	5%	1%	6%	14%	2%	1%	5%	1%	1%	3%	13%	0%	5%	3%
Presched	27%	33%	20%	4%	2%	35%	62%	22%	44%	26%	36%	30%	1%	25%	44%	16%	21%	7%	39%	49%	23%	61%	29%	2%	2%	40%	29%	31%	13%	20%	13%	26%
Day_1	12%	5%	2%	9%	46%	62%	50%	23%	7%	2%	16%	13%	0%	4%	21%	8%	13%	21%	34%	1%	20%	58%	7%	23%	9%	11%	14%	1%	4%	5%	8%	16%
Day_2	5%	30%	6%	19%	42%	32%	62%	2%	13%	9%	9%	30%	57%	22%	48%	4%	39%	48%	38%	46%	20%	60%	26%	20%	0%	32%	52%	0%	17%	2%	27%	26%
Day_3	28%	60%	19%	13%	47%	32%	36%	11%	25%	9%	18%	19%	26%	10%	29%	20%	31%	45%	36%	36%	7%	57%	28%	7%	11%	44%	18%	8%	31%	2%	35%	26%
Day_4	21%	5%	1%	32%	1%	45%	36%	44%	8%	5%	18%	12%	59%	14%	21%	28%	23%	8%	38%	57%	18%	58%	16%	17%	17%	25%	24%	32%	47%	3%	37%	25%
Day_5	17%	10%	5%	19%	29%	33%	21%	44%	33%	38%	50%	12%	8%	16%	33%	14%	33%	3%	43%	31%	3%	47%	12%	11%	17%	35%	52%	54%	38%	34%	8%	26%
Historical	42%	4%	15%	7%	6%	17%	52%	28%	63%	50%	67%	23%	4%	20%	39%	35%	14%	8%	44%	58%	8%	44%	15%	12%	6%	44%	48%	67%	40%	67%	29%	31%

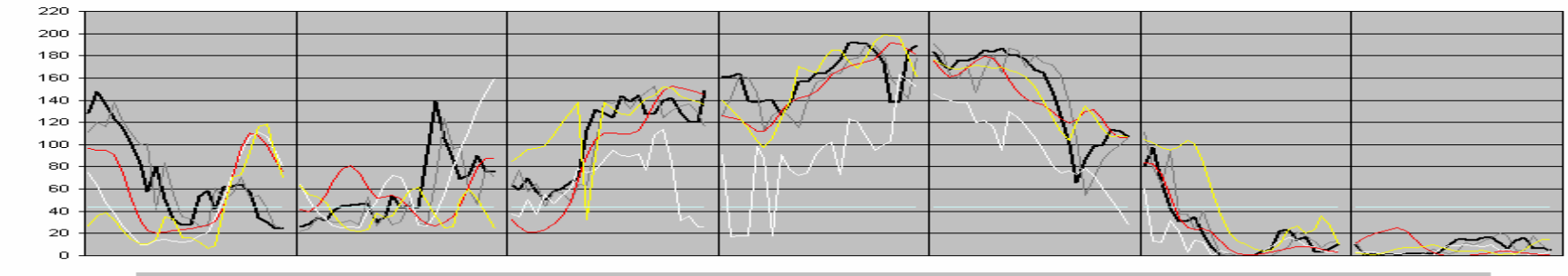
Weekly Forecast Results

please see next slide

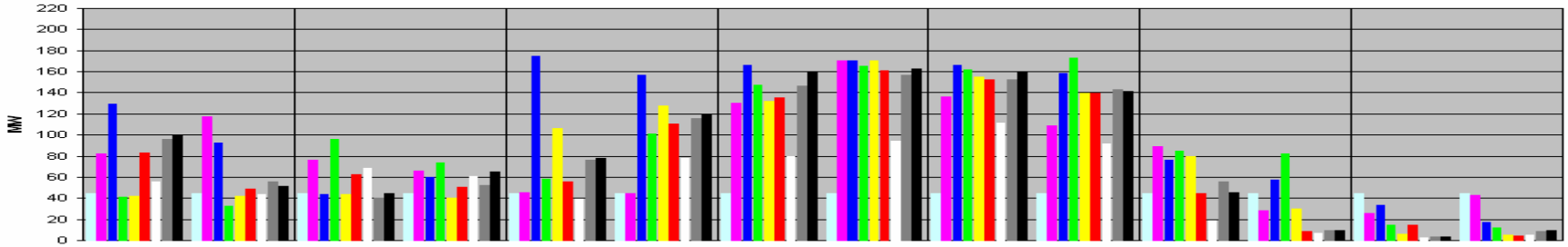
Weekly Summary Deviation
Mar 05, 2006 to Mar 11, 2006

Note:
Light Load: 10PM - 6AM
Heavy Load: 6AM - 10PM





Historical | Day -5 | Day -4 | Day -3 | Day -2 | Day -1 | PreSched | Realtime | Actual



	Sunday LL	Sunday HL	Monday LL	Monday HL	Tuesday LL	Tuesday HL	Wednesday LL	Wednesday HL	Thursday LL	Thursday HL	Friday LL	Friday HL	Saturday LL	Saturday HL	Absolute Average
Historical	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	44.1	
	-26.9%	-3.6%	-0.2%	-10.2%	-16.4%	-36.1%	-55.6%	-56.9%	-55.3%	-46.8%	-0.8%	16.5%	19.6%	16.7%	25.8%
Day -5	82.1	117.2	76.3	65.8	45.1	44.6	130.1	170.0	135.9	109.0	89.4	28.3	26.1	43.2	
	-8.6%	31.6%	15.2%	0.3%	-15.9%	-35.9%	-14.2%	3.7%	-11.1%	-15.6%	21.0%	8.9%	10.9%	16.3%	14.9%
Day -4	129.0	92.0	44.0	59.7	174.8	156.5	165.7	170.1	165.7	158.7	76.0	57.2	33.3	17.0	
	13.9%	19.5%	-0.3%	-2.7%	46.5%	17.9%	2.9%	3.7%	3.2%	8.3%	14.5%	22.9%	14.4%	3.7%	12.5%
Day -3	41.0	32.4	96.2	73.4	58.0	101.0	147.0	165.4	161.4	172.6	84.4	82.0	14.3	12.3	
	-28.4%	-9.2%	24.8%	3.9%	-9.7%	-8.8%	-6.1%	1.5%	1.2%	15.0%	18.6%	34.8%	5.3%	1.4%	12.0%
Day -2	41.9	42.4	43.3	40.1	106.1	127.7	131.4	170.6	155.2	139.7	79.7	29.9	5.8	5.4	
	-28.0%	-4.4%	-0.6%	-12.1%	13.4%	4.1%	-13.6%	3.9%	-1.8%	-0.8%	16.3%	9.7%	1.2%	-1.9%	8.0%
Day -1	83.2	48.7	62.7	50.8	55.6	110.2	135.1	160.5	152.7	139.9	44.8	8.5	14.9	4.3	
	-8.1%	-1.3%	8.7%	-7.0%	-10.9%	-4.3%	-11.8%	-0.9%	-3.0%	-0.7%	-0.4%	-0.6%	5.6%	-2.4%	4.7%
PreSched	55.6	43.9	68.1	60.5	39.1	78.1	80.0	94.4	111.3	92.0	18.8	6.9	2.4	4.8	
	-21.3%	-3.7%	11.3%	-2.3%	-18.8%	-19.8%	-38.3%	-32.7%	-23.0%	-23.7%	-13.0%	-1.4%	-0.5%	-2.2%	15.1%
RealTime	95.9	55.6	40.4	52.1	76.3	115.7	146.4	156.7	152.6	143.1	56.0	9.8	3.8	8.3	
	-2.0%	2.0%	-2.0%	-6.4%	-1.0%	-1.7%	-6.4%	-2.8%	-3.1%	0.8%	4.9%	0.0%	0.2%	-0.5%	2.4%
Actual	100.0	51.5	44.6	65.3	78.2	119.2	159.7	162.4	159.0	141.4	45.7	9.7	3.4	9.4	

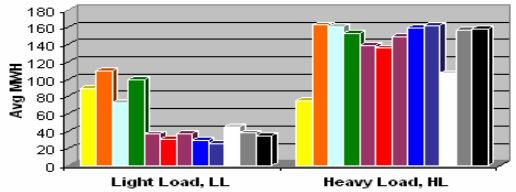
Daily Forecast Results

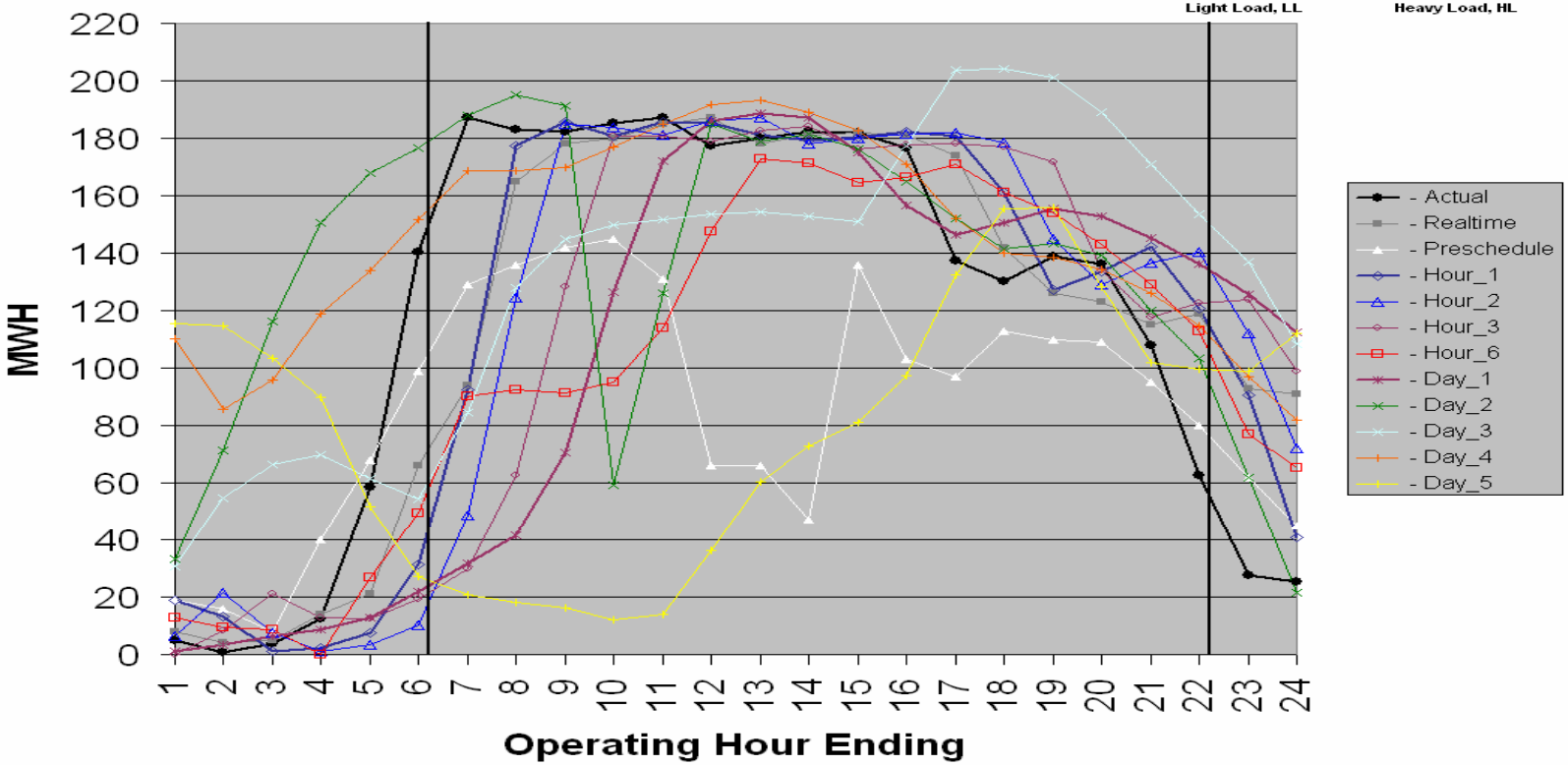
please see next slide

February 2006

Sat	Sun	Mon	Tue	Wed	Thu	Fri
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	1	2	3
4	5	6	7	8	9	10

Daily Forecasts for February 28, 2006





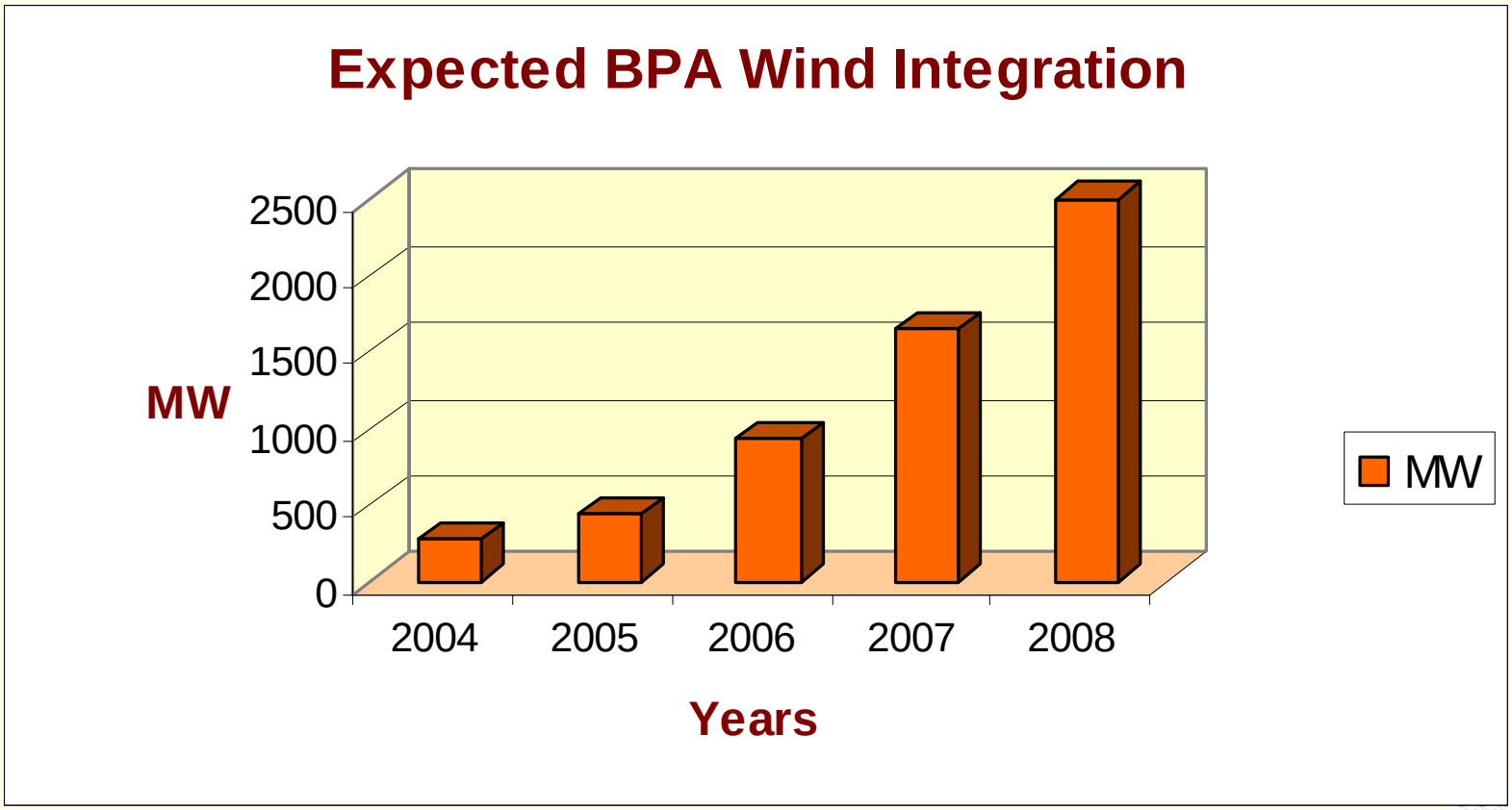
Forecast Percent of Actual

Note:
Light Load: 10PM - 6AM
Heavy Load: 6AM - 10PM

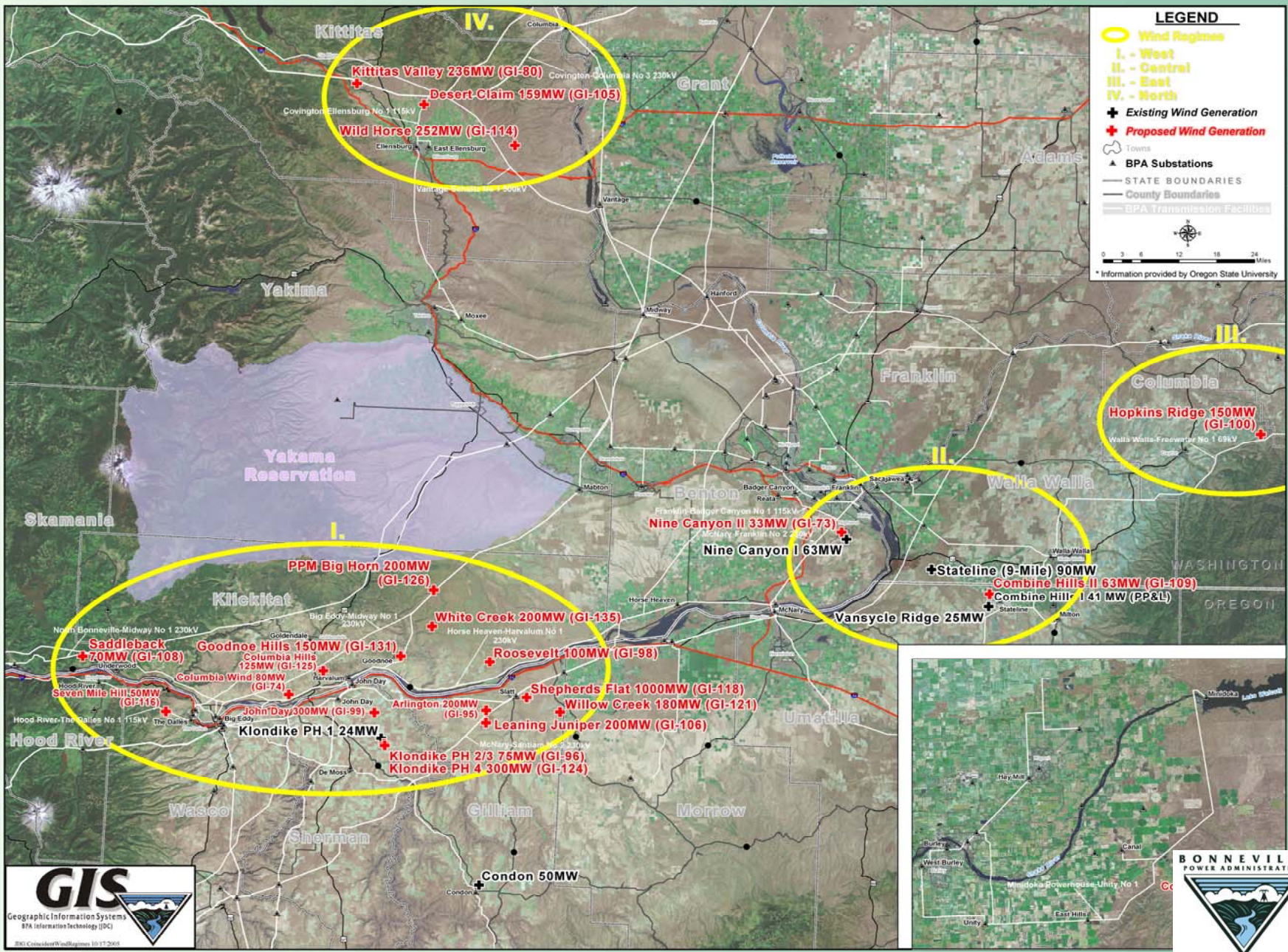
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	LL	HL
Realtime	162.6	425.5	136.2	113.9	36.0	47.0	50.2	90.2	97.7	97.1	98.9	105.3	98.9	99.4	100.0	102.6	126.7	109.1	90.6	90.4	106.4	189.5	336.5	360.4	110.4	99.0
Preschedule	386.1	####	217.9	325.4	116.4	70.4	68.9	74.4	78.0	78.2	70.0	37.2	36.7	25.8	74.8	58.4	70.6	86.8	79.1	80.1	87.9	127.4	224.3	178.2	130.5	67.2
Hour - 1	380.1	####	29.5	17.9	12.6	22.4	49.4	97.0	101.8	97.5	99.2	104.4	100.6	98.5	99.1	103.3	131.7	123.9	91.4	98.1	131.5	192.1	327.6	161.7	75.0	102.3
Hour - 2	129.9	####	205.2	10.2	5.6	7.3	26.0	68.2	101.5	99.2	96.9	104.7	104.0	97.8	98.9	102.8	132.4	137.2	104.3	94.8	126.5	223.5	404.9	286.0	85.6	100.4
Hour - 3	0.0	867.5	570.8	104.6	21.6	13.7	16.0	34.3	70.5	97.5	96.7	100.7	101.4	101.2	96.9	100.7	129.8	136.0	123.6	98.6	109.0	195.1	448.3	392.1	108.5	94.0
Hour - 6	258.1	992.2	241.1	0.0	45.8	35.2	48.1	50.5	50.1	51.3	60.9	83.0	96.1	94.1	90.4	94.3	124.6	123.8	110.7	105.1	119.5	179.5	278.1	258.6	91.1	85.8
(PreS) Day - 1	26.6	359.9	174.3	69.5	21.9	15.7	16.9	22.6	38.7	68.2	92.0	104.8	104.7	102.8	96.2	88.7	106.7	115.6	112.0	112.3	134.2	216.8	454.6	445.5	106.9	87.6
Day - 2	673.8	####	####	####	287.2	125.7	100.4	106.6	105.1	32.0	67.3	104.2	99.4	99.7	97.0	93.5	110.7	108.8	103.3	102.3	110.9	164.8	223.3	85.1	292.0	96.5
Day - 3	623.9	####	####	568.6	105.5	38.7	45.2	70.0	79.6	80.8	81.2	86.5	85.8	83.8	83.1	100.5	148.5	156.8	144.7	139.0	158.1	244.5	495.2	429.5	213.0	101.4
Day - 4	####	####	####	968.1	229.1	108.1	90.1	92.2	93.1	95.5	98.8	107.9	107.3	103.8	100.4	96.8	110.6	107.5	99.5	98.6	116.7	182.8	351.2	324.5	320.0	102.6
Day - 5	####	####	####	730.8	88.2	19.2	11.0	9.9	9.0	6.6	7.4	20.4	33.5	39.9	44.6	55.1	96.5	119.6	112.2	94.2	94.2	158.7	357.5	444.0	260.4	47.4

BONNEVILLE POWER ADMINISTRATION

Expansion of Wind in the BPA Control Area

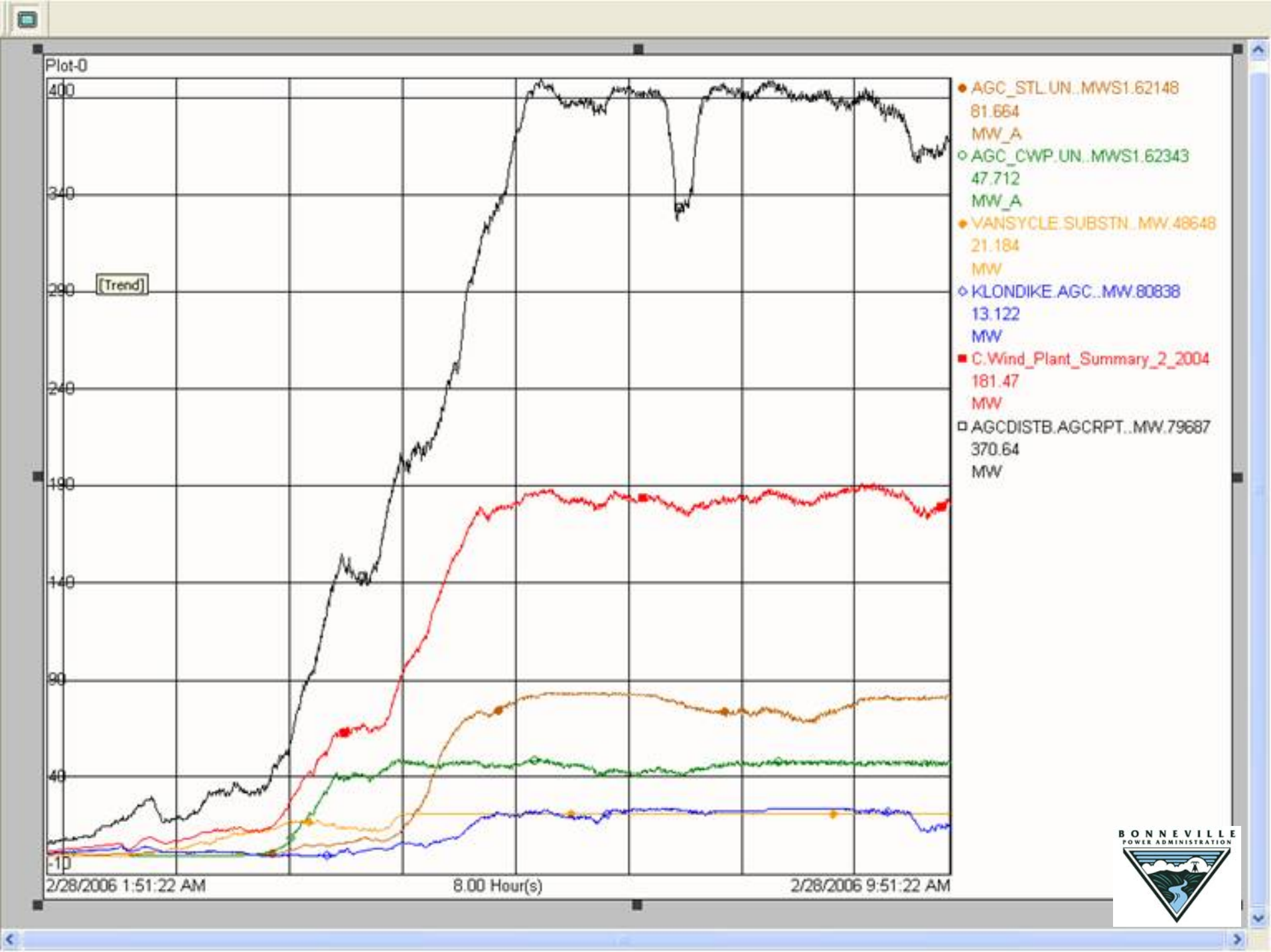


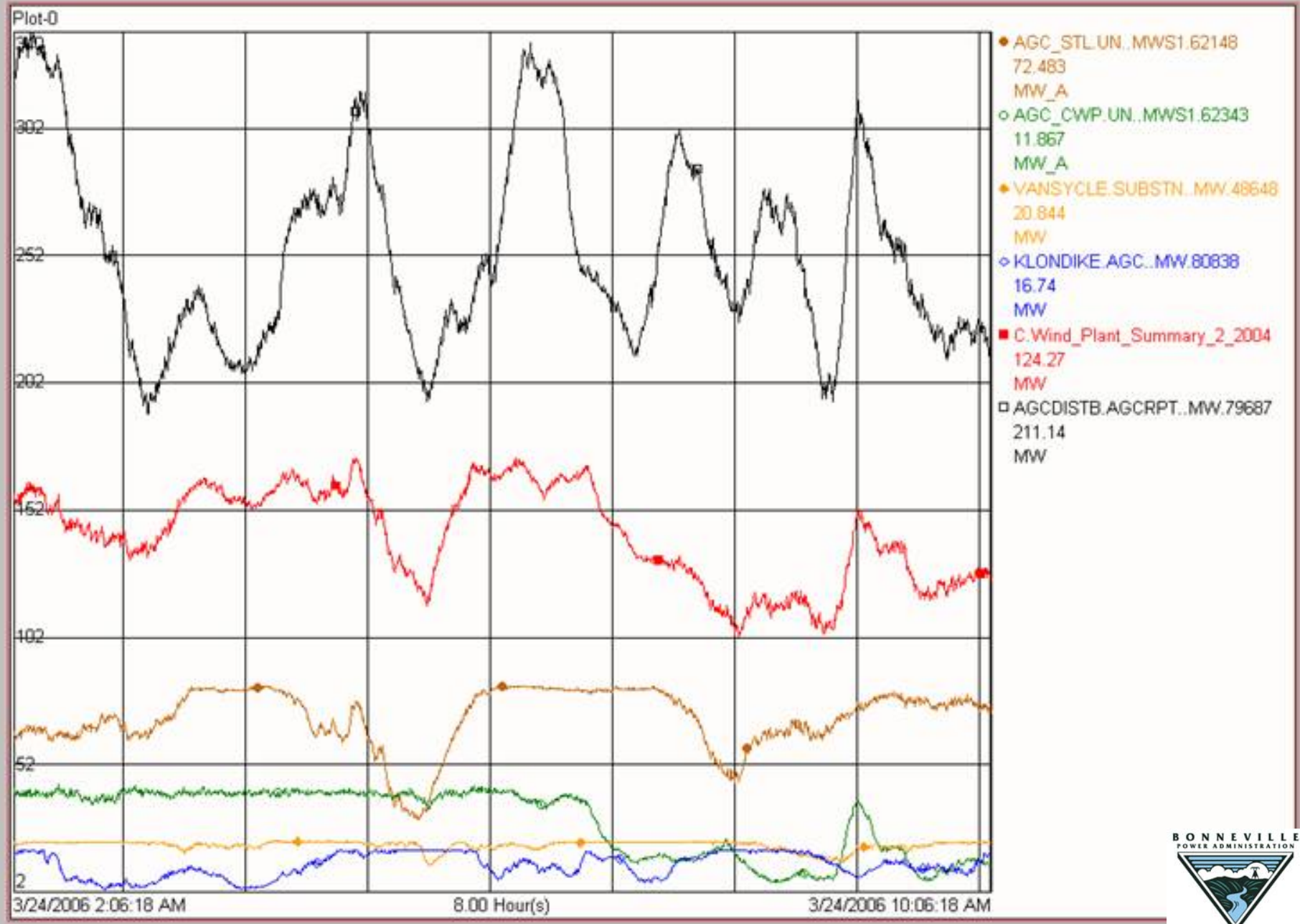
Coincident Wind Regimes



Within the Hour Wind Ramps in the mid-Columbia – Business Case

- Coincidental wind regimes in the mid-Columbia basin – within the hour (Oregon State)
- Large wind plants locating in small geographic areas – a function of commercial wind and available transmission
- Documented within the hour coincident wind ramps in PBL
- Issue – **unscheduled wind energy entering the BPA control area**
- Impact – Columbia Vista, NRTO, PBL/TBL Scheduling & Operations


Plot-0
400
340
290
240
190
140
90
40
-10
[Trend]
2/28/2006 1:51:22 AM
8.00 Hour(s)
2/28/2006 9:51:22 AM
AGC_STL.UN..MWS1.62148
81.664
MW_A
AGC_CWP.UN..MWS1.62343
47.712
MW_A
VANSYCLE.SUBSTN..MW.48648
21.184
MW
KLONDIKE.AGC..MW.80838
13.122
MW
C.Wind_Plant_Summary_2_2004
181.47
MW
AGCDISTB.AGCRPT..MW.79687
370.64
MW
BONNEVILLE
POWER ADMINISTRATION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11.867
MW_A
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MW
KLONDIKE.AGC..MW.80838
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MW
C.Wind_Plant_Summary_2_2004
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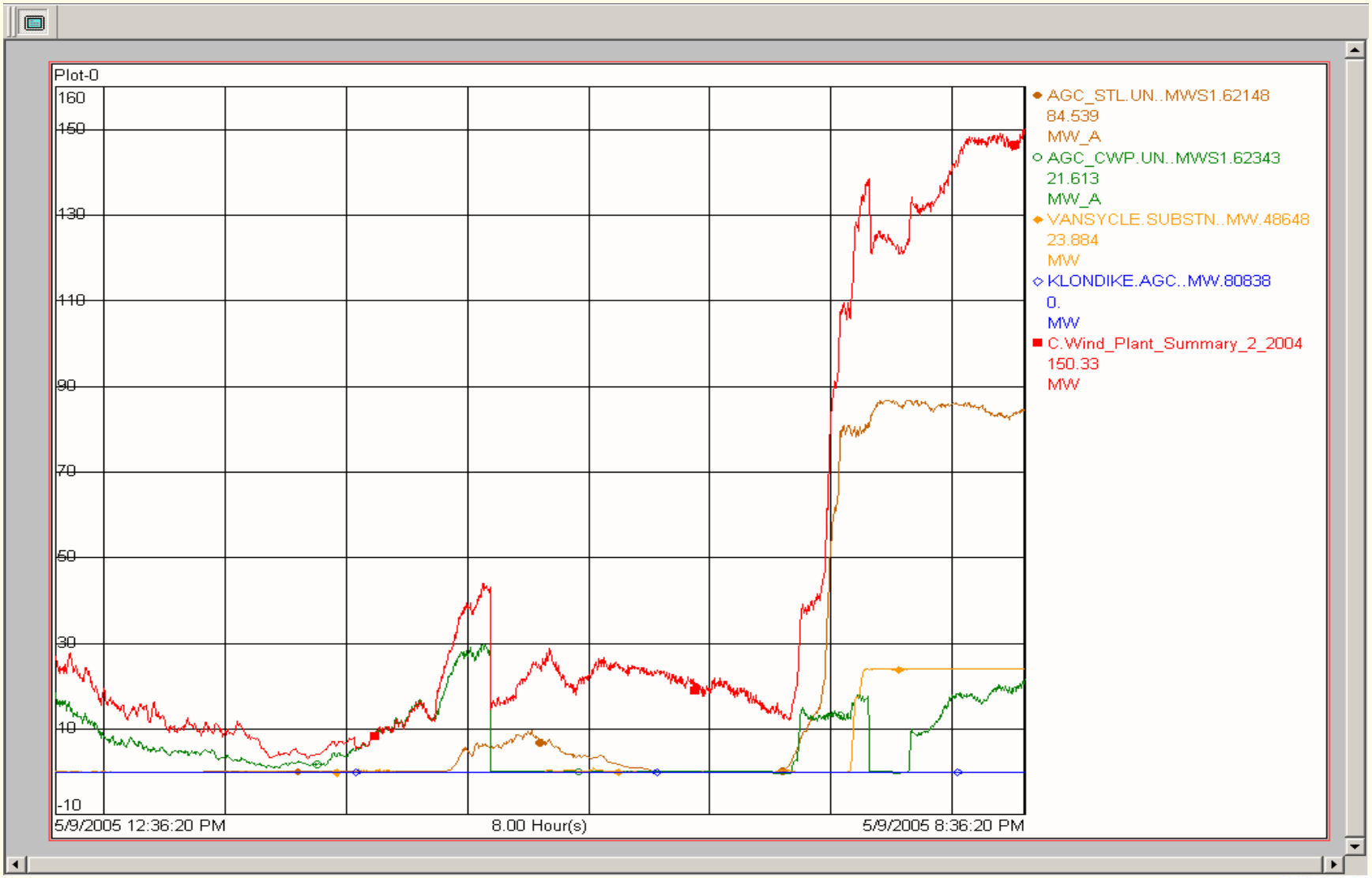
MW
AGCDISTB.AGCRPT..MW.79687
211.14
MW
3/24/2006 2:06:18 AM
8.00 Hour(s)
3/24/2006 10:06:18 AM

Coordination Benefits to PBL/TBL on Wind Forecasting

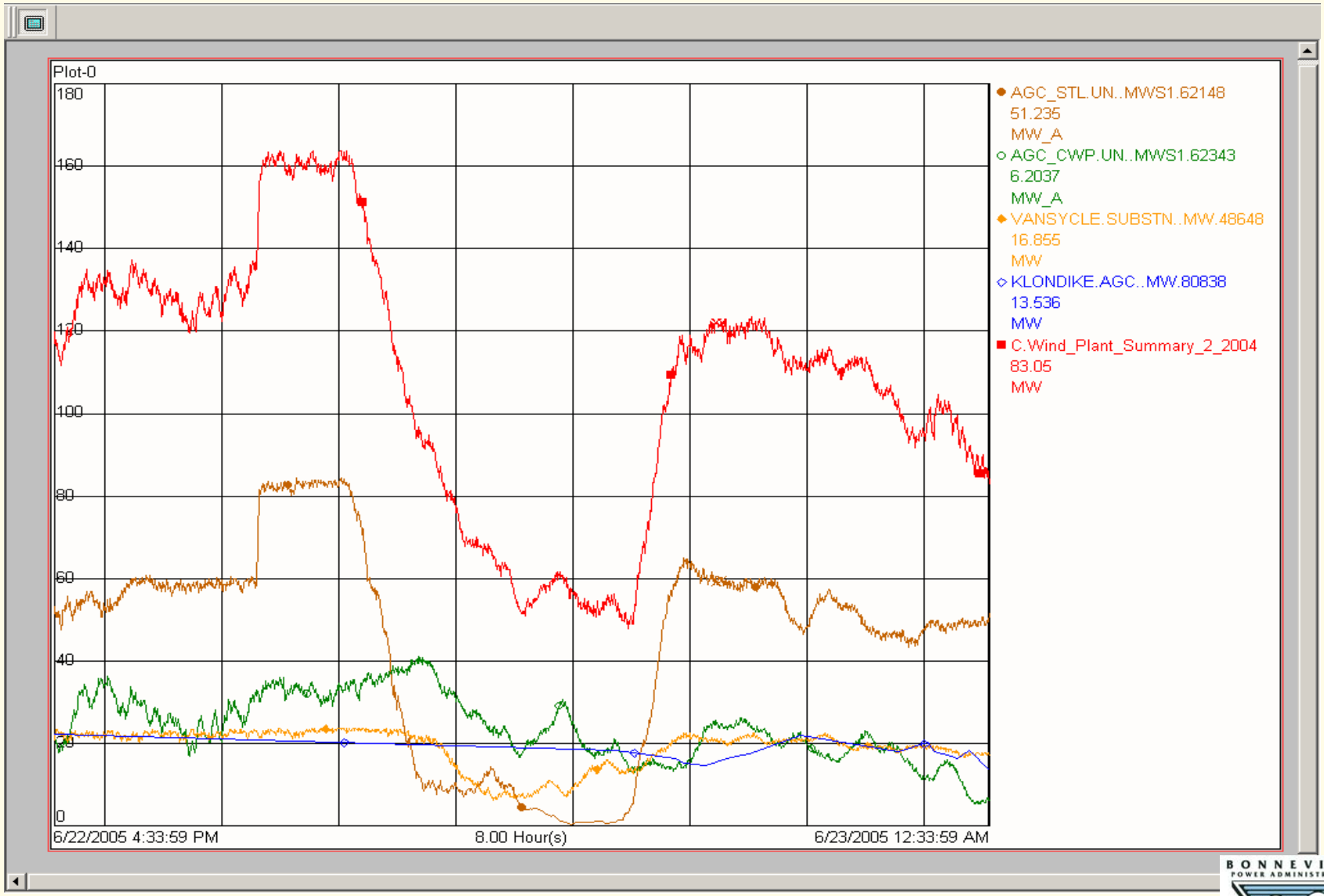
- Concurrently, given current product/tariff/risks, foreknowledge of upcoming wind, both by PBL and TBL, makes efficient use of available resources
- Less available capacity is needed (more to follow)
- Efficient use of hydro resources (PBL) – Columbia Vista & NRTO
- Efficient use of transmission assets (TBL) – congestion management, system stability, redispatch

Coordination Benefits to PBL/TBL on Wind Forecasting cont.

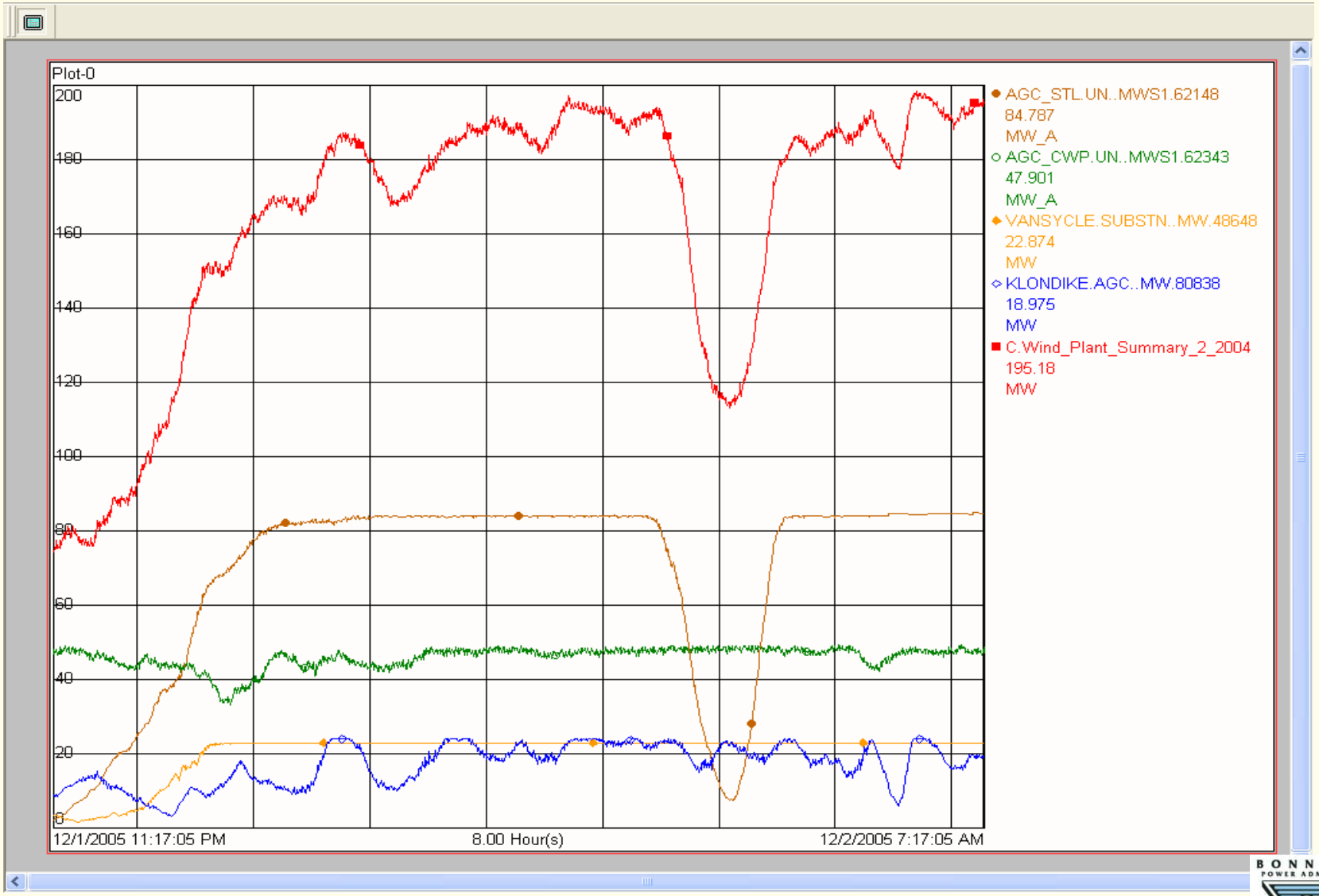
- Wind plant owner/operators may creatively schedule to minimize generation imbalance
- **Day ahead schedule may be unreliable**
- Within the hour and day ahead wind forecasting by BPA for all wind generators may help
- R/D – no within the hour wind forecasting system exists today – 3Tier prototype system
- System may take 1 ½ to 2 years to develop
- Parallel effort – SCE, CALISO & others



BONNEVILLE POWER ADMINISTRATION



BONNEVILLE POWER ADMINISTRATION



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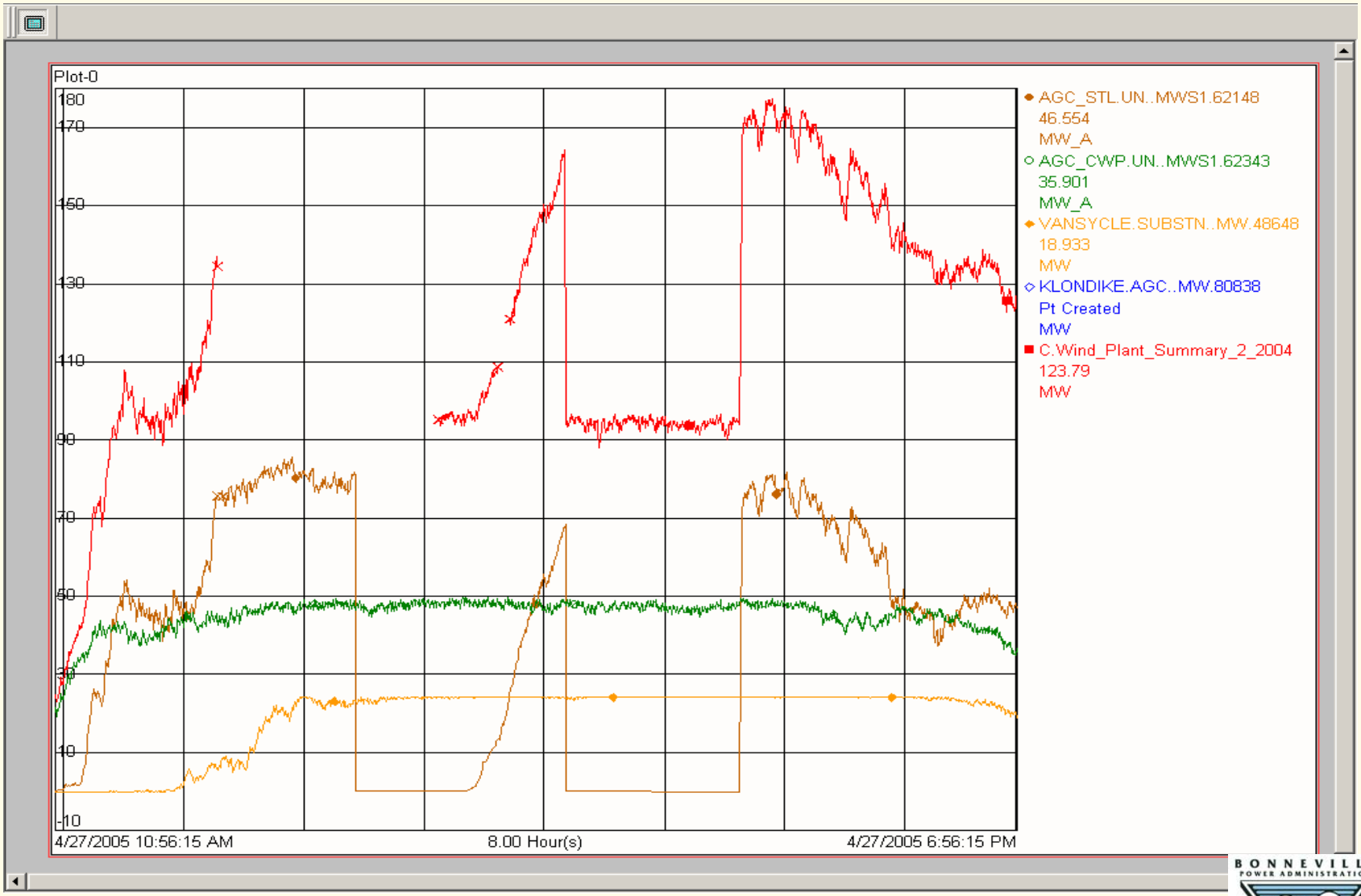
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150
130
110
90
70
50
30
10
-10
4/27/2005 10:56:15 AM
8.00 Hour(s)
4/27/2005 6:56:15 PM
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46.554
MW_A
AGC_CWP.UN..MWS1.62343
35.901
MW_A
VANSYCLE.SUBSTN..MW.48648
18.933
MW
KLONDIKE.AGC..MW.80838
Pt Created
MW
C.Wind_Plant_Summary_2_2004
123.79
MW

Within the Hour Wind Ramps – Impacts to Columbia Vista and NRTO

- Unscheduled energy entering the control area
- Regulation capacity – small, but significant
- Load following capacity (NRTO) – significant
- Columbia Vista – significant up and down
- Transmission impacts – congestion management, system stability
- **Efficient use of available resources**

Prototype Wind Ramp Forecasting System

- **Current** wind energy forecasting models **never designed** to forecast within the hour wind ramps
- **Innovative techniques** will be needed – upwind sensors tuned to each wind project, ground based Radar to monitor a 50 mile (radius) area
- **Identify ramping vulnerability** in the preschedule – coordinate the generation that will needed to support it
- **Update** through out the **operating day**
- **Track real time** when the likelihood of a ramp(s) is **imminent**

BONNEVILLE POWER ADMINISTRATION

Wind Forecasting – Next Steps?

- **BPA may forecast for wind plants in the control area – motivating wind plant owner/ operators to schedule to the forecast**
- **Efficient use of Federal resources in the BPA control area**
- **PBL/TBL partnership to share wind energy data to serve their individual needs**
- **Finding a way to work together so SOC rules are maintained**
- **BPA's historic role – innovative solutions that serve the Pacific Northwest**

Questions and Comments?