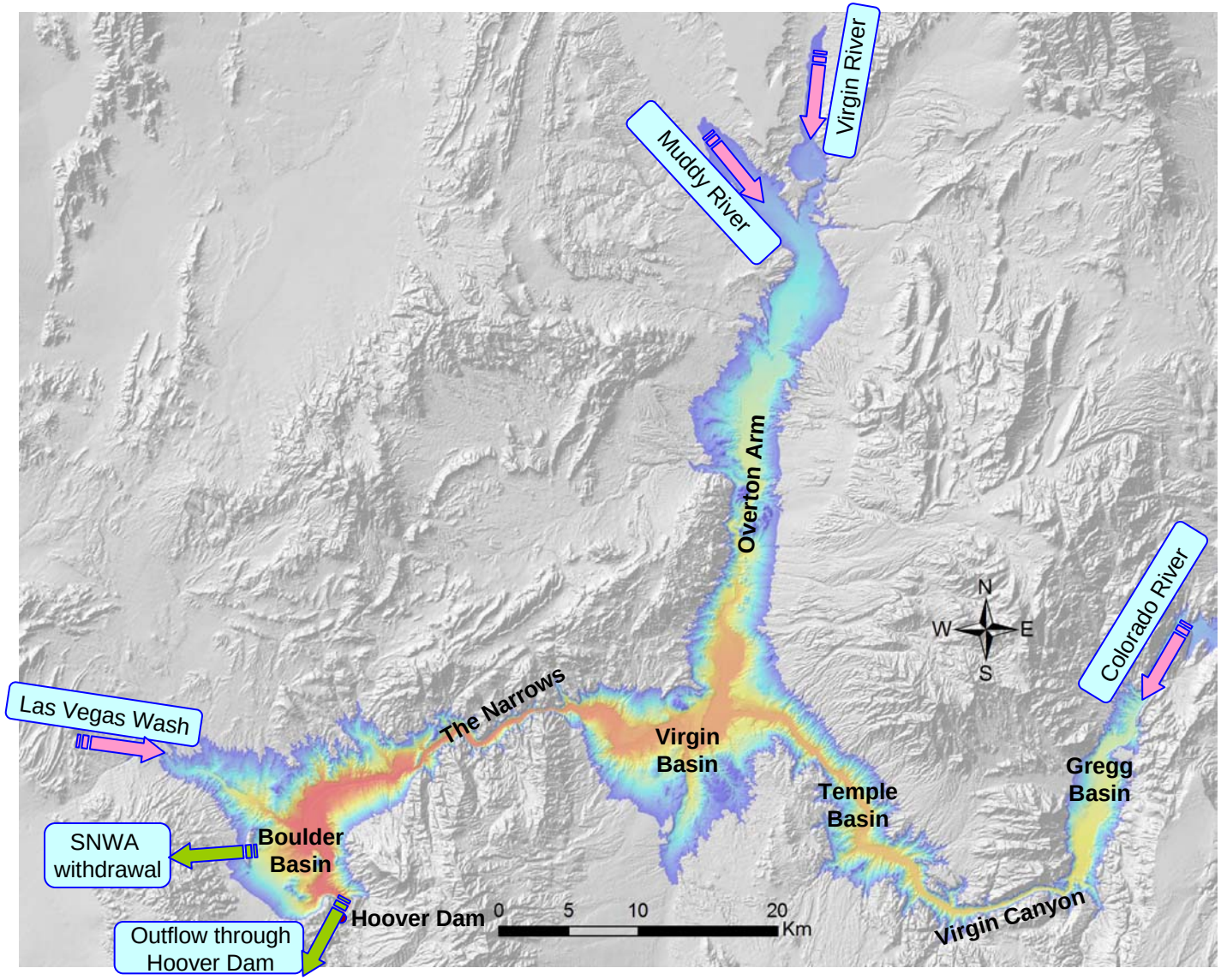
Lake Mead – Data Analysis
Phosphorus Budget

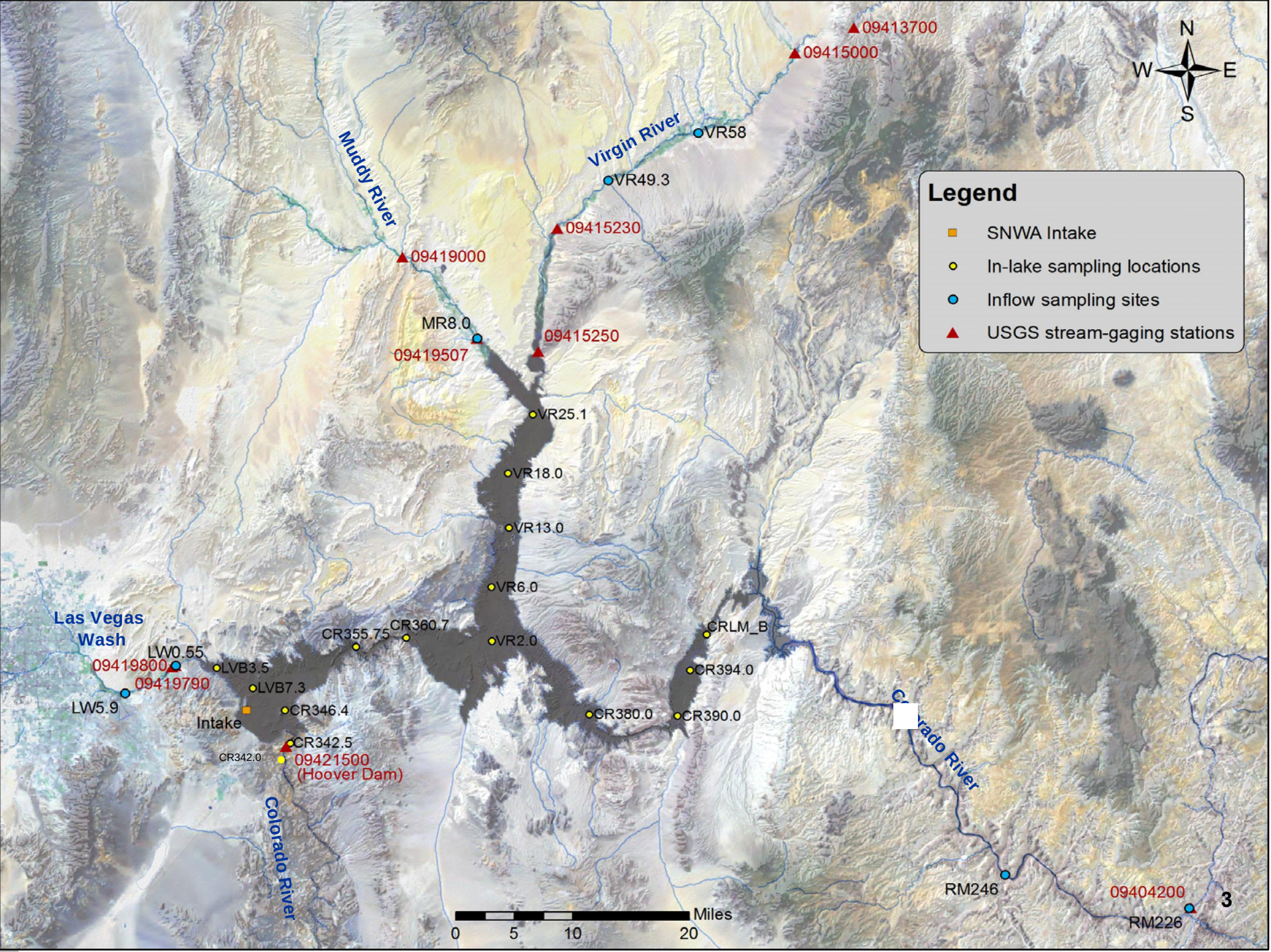
Flow Science Incorporated

On behalf of CWC and SNWA

February 23, 2009

Overall Mass Balance




09413700
09415000
N
W
E
S
Virgin River
VR58
VR49.3
Muddy River
09415230
09419000
MR8.0
09415250
09419507
VR25.1
VR18.0
VR13.0
VR6.0
VR2.0
CR355.75
CR360.7
CRLM_B
CR394.0
CR380.0
CR390.0
Las Vegas
Wash
LW0.55
09419800
LVB3.5
09419790
LVB7.3
LW5.9
Intake
CR346.4
CR342.5
CR342.0
09421500
(Hoover Dam)
Colorado River
Colorado River
RM246
09404200
RM226
Miles
0
5
10
20
Legend
SNWA Intake
In-lake sampling locations
Inflow sampling sites
USGS stream-gaging stations

Colorado River Phosphorus Loadings

Year	Annual Average Flow Rate (cfs)	Annual Average TP		Annual Average Ortho-P	
		Concentration (mg/L)	Loading (lbs/day)	Concentration (mg/L)	Loading (lbs/day)
2000	13,000	--	--	--	--
2001	12,000	--	--	--	--
2002	12,000	0.25	17,000	0.009	620
2003	12,000	0.68	44,000	0.009	610
2004	13,000	0.36	25,000	0.005	320
2005	13,000	0.23	17,000	0.007	470
2006	13,000	0.38	28,000	0.005	340
2007	13,000	0.99	72,000	0.004	260

Virgin River Phosphorus Loadings

Year	Annual Average Flow Rate (cfs)	Annual Average TP		Annual Average Ortho-P	
		Concentration (mg/L)	Loading (lbs/day)	Concentration (mg/L)	Loading (lbs/day)
2000	120	--	--	--	--
2001	110	--	--	--	--
2002	78	--	--	--	--
2003	77	--	--	--	--
2004	140	0.058	66	--	--
2005	580	0.063	280	--	--
2006	170	0.36	310	0.021	11
2007	94	0.13	59	0.031	19

Muddy River Phosphorus Loadings

Year	Annual Average Flow Rate (cfs)	Annual Average TP		Annual Average Ortho-P	
		Concentration (mg/L)	Loading (lbs/day)	Concentration (mg/L)	Loading (lbs/day)
2000	6.6	--	--	--	--
2001	3.4	--	--	--	--
2002	2.9	--	--	0.14	2.0
2003	2.7	--	--	0.10	1.6
2004	8.7	--	--	0.065	2.1
2005	18.3	0.10	5.8	0.10	5.7
2006	5.4	0.12	4.3	0.12	4.3
2007	2.7	0.15	2.1	0.15	2.1

Las Vegas Wash Phosphorus Loadings

Year	Annual Average Flow Rate (cfs)	Annual Average TP		Annual Average Ortho-P	
		Concentration (mg/L)	Loading (lbs/day)	Concentration (mg/L)	Loading (lbs/day)
2000	220	0.34	440	0.21	260
2001	240	0.23	320	0.15	200
2002	250	0.22	310	0.13	180
2003	270	0.21	310	0.099	140
2004	280	0.17	270	0.075	120
2005	300	0.12	220	0.048	80
2006	300	0.12	200	0.067	110
2007	290	0.12	190	0.082	130

Phosphorus Losses through Hoover Dam

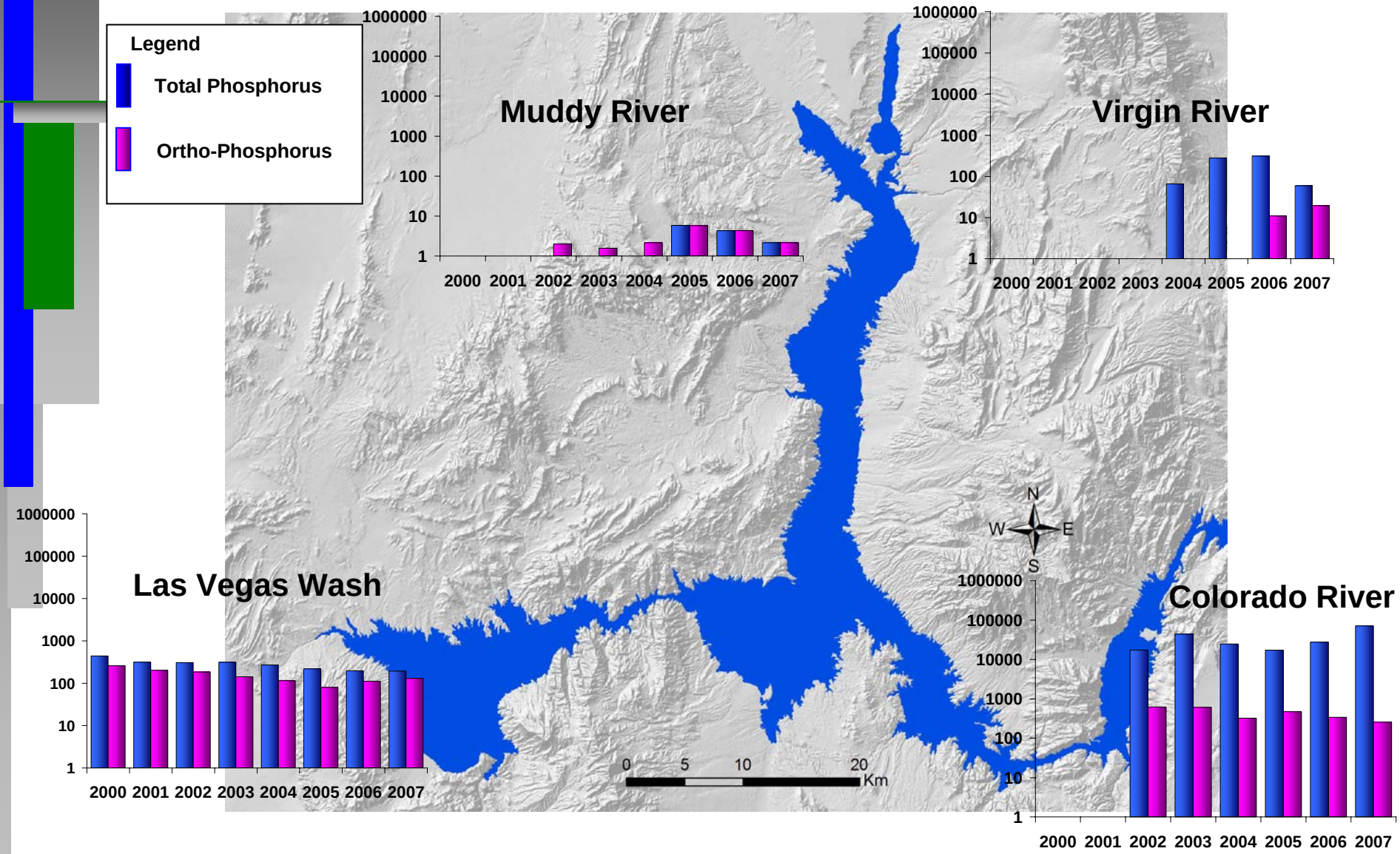
Year	Annual Average Flow Rate (cfs)	Annual Average TP		Annual Average Ortho-P	
		Concentration (mg/L)	Loading (lbs/day)	Concentration (mg/L)	Loading (lbs/day)
2000	15,000	0.004	300	0.003	210
2001	14,000	0.004	330	0.004	260
2002	14,000	0.005	370	0.004	270
2003	13,000	0.005	320	0.003	240
2004	13,000	0.005	350	0.003	210
2005	11,000	0.006	370	0.003	190
2006	13,000	0.004	300	0.004	250
2007	13,000	0.005(0.007)*	310 (510)*	0.004(0.001)*	280 (84)*

* Numbers in parentheses are based phosphorus data from SNWA

Phosphorus Losses through SNWA Intakes

Year	Annual Average Flow Rate (cfs)	Annual Average TP		Annual Average Ortho-P	
		Flow Weighted Concentration (mg/L)	Loading (lbs/day)	Flow Weighted Concentration (mg/L)	Loading (lbs/day)
2000	610	0.007	23	--	--
2001	620	0.008	27	--	--
2002	640	0.009	30	--	--
2003	640	0.005	19	--	--
2004	620	0.008	26	--	--
2005	640	0.011	39	0.004	13
2006	700	0.005	19	0.003	13
2007	700	0.005	20	0.004	13

Annual Phosphorus Loadings (lbs/day)



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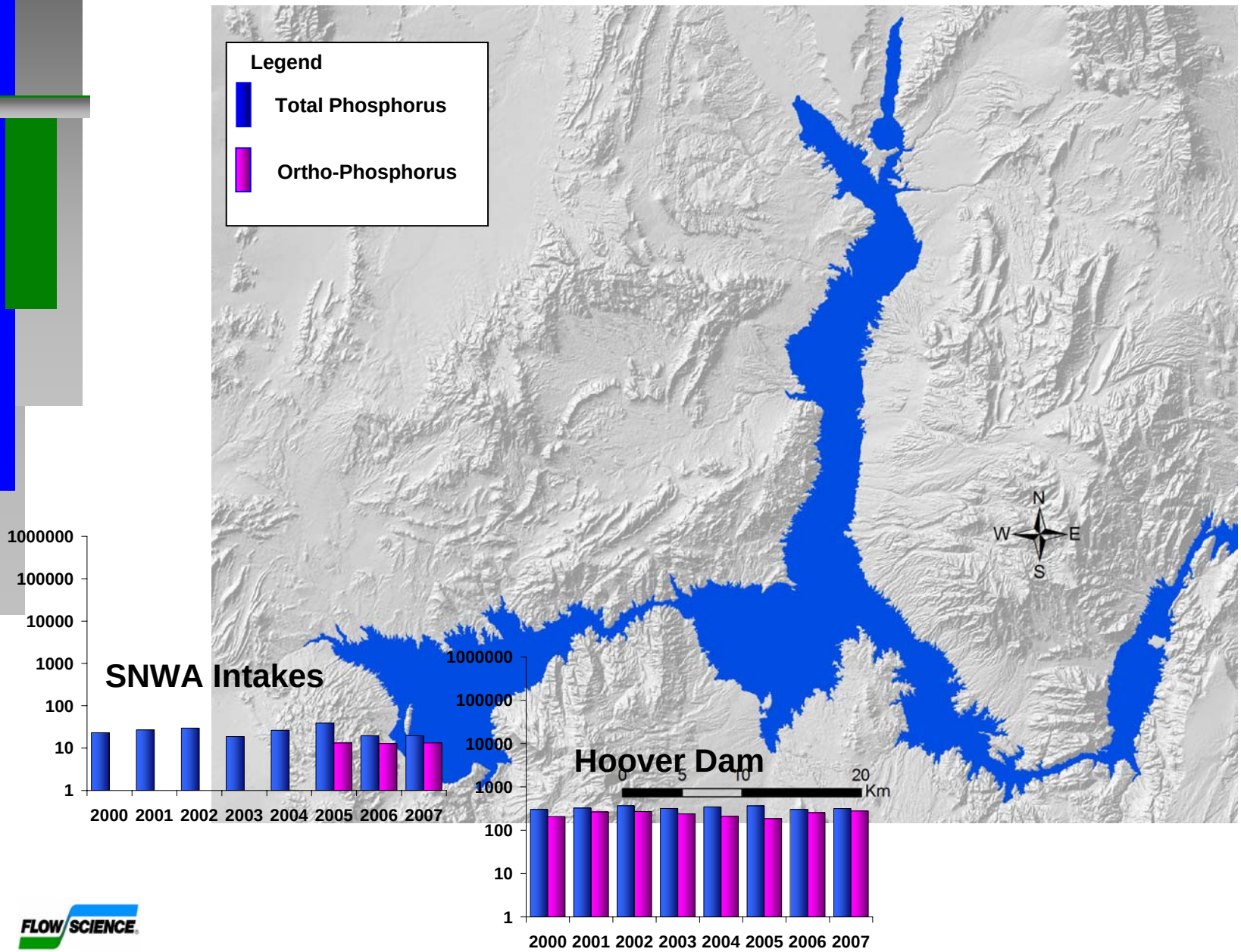
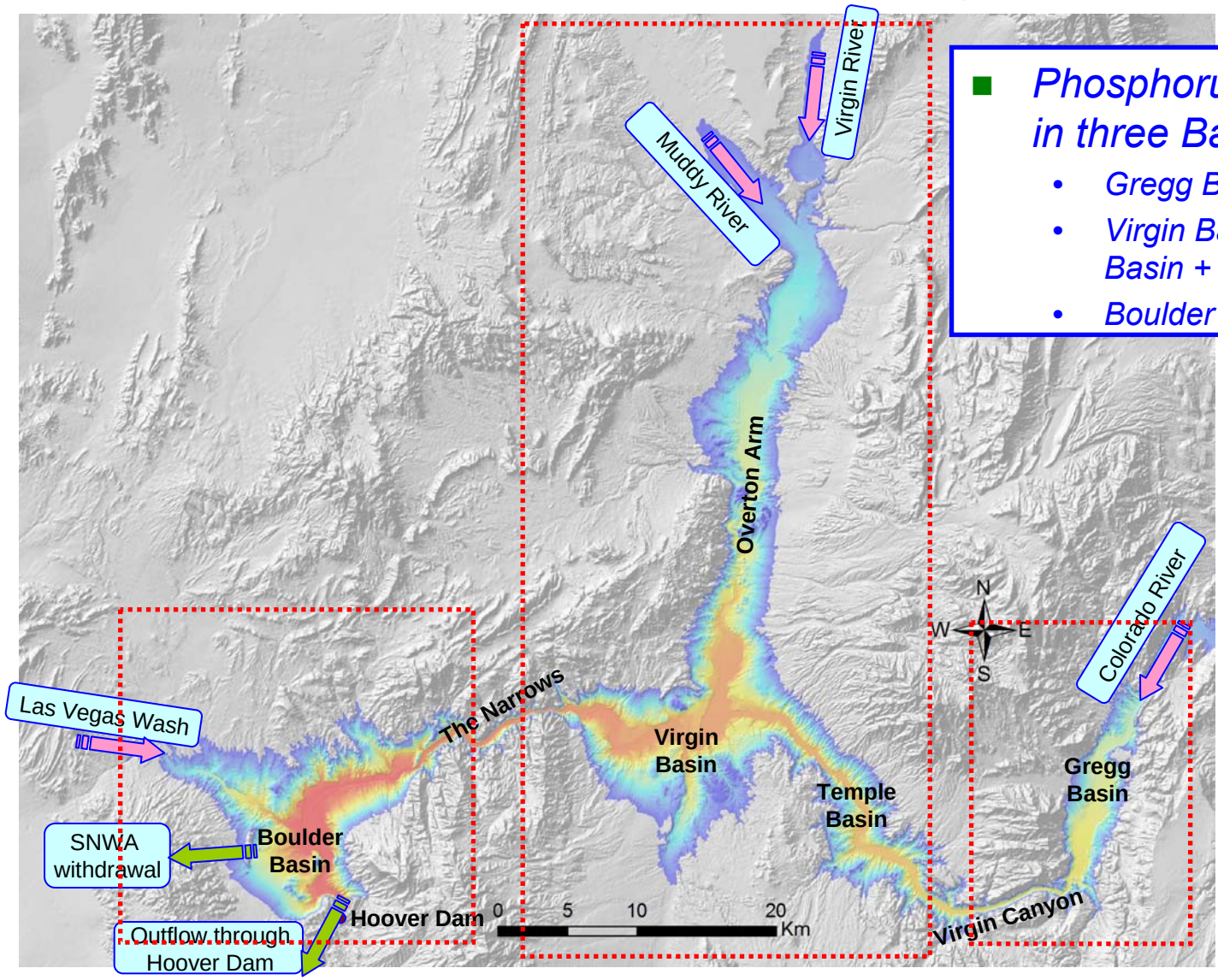
Annual Phosphorus Losses (lbs/day)



Approach – Phosphorus Budgets for 1997



- *Phosphorus balance in three Basins*
  - *Gregg Basin*
  - *Virgin Basin + Temple Basin + Overton Arm*
  - *Boulder Basin*

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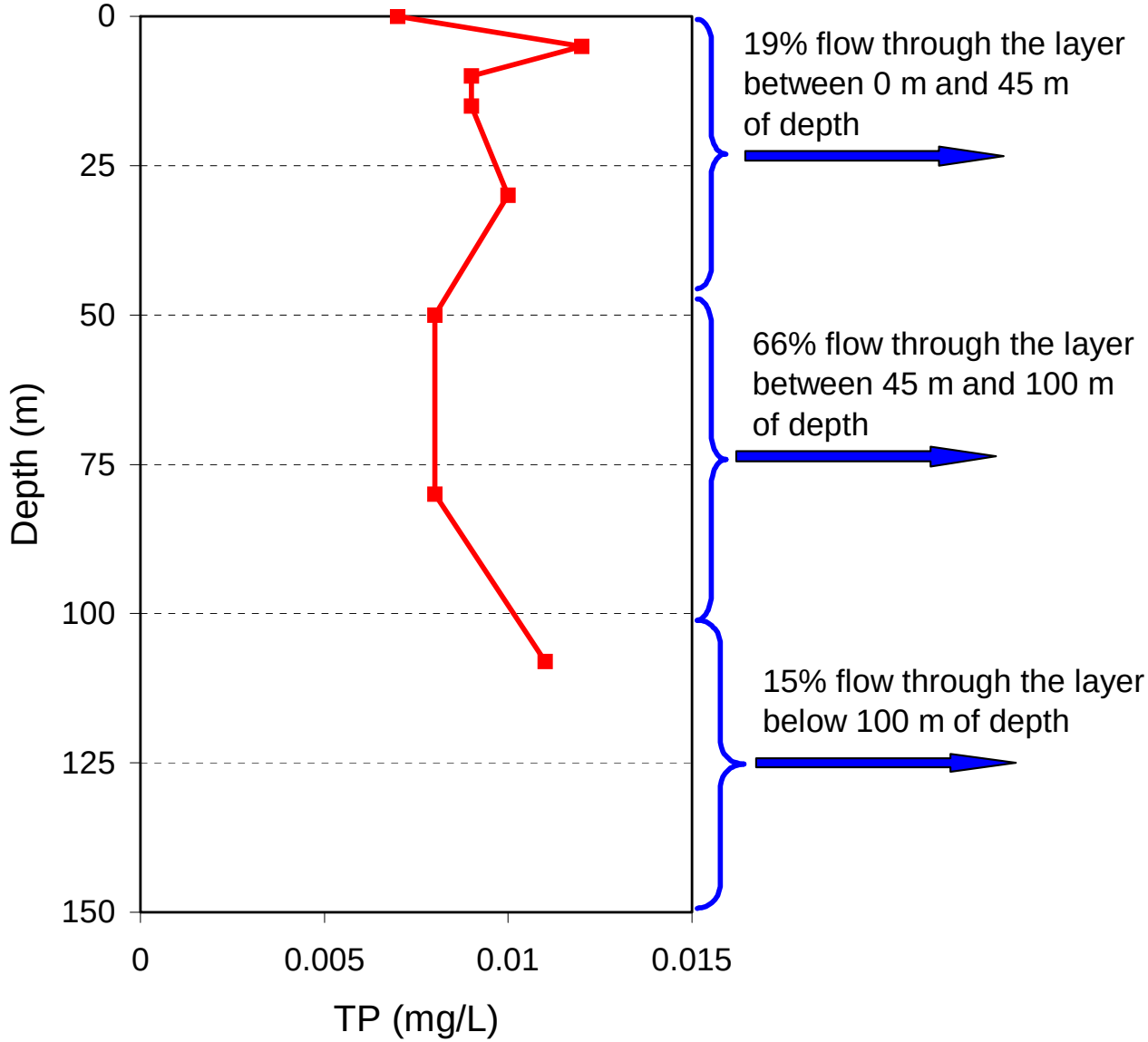
Phosphorus Budget in the Gregg Basin

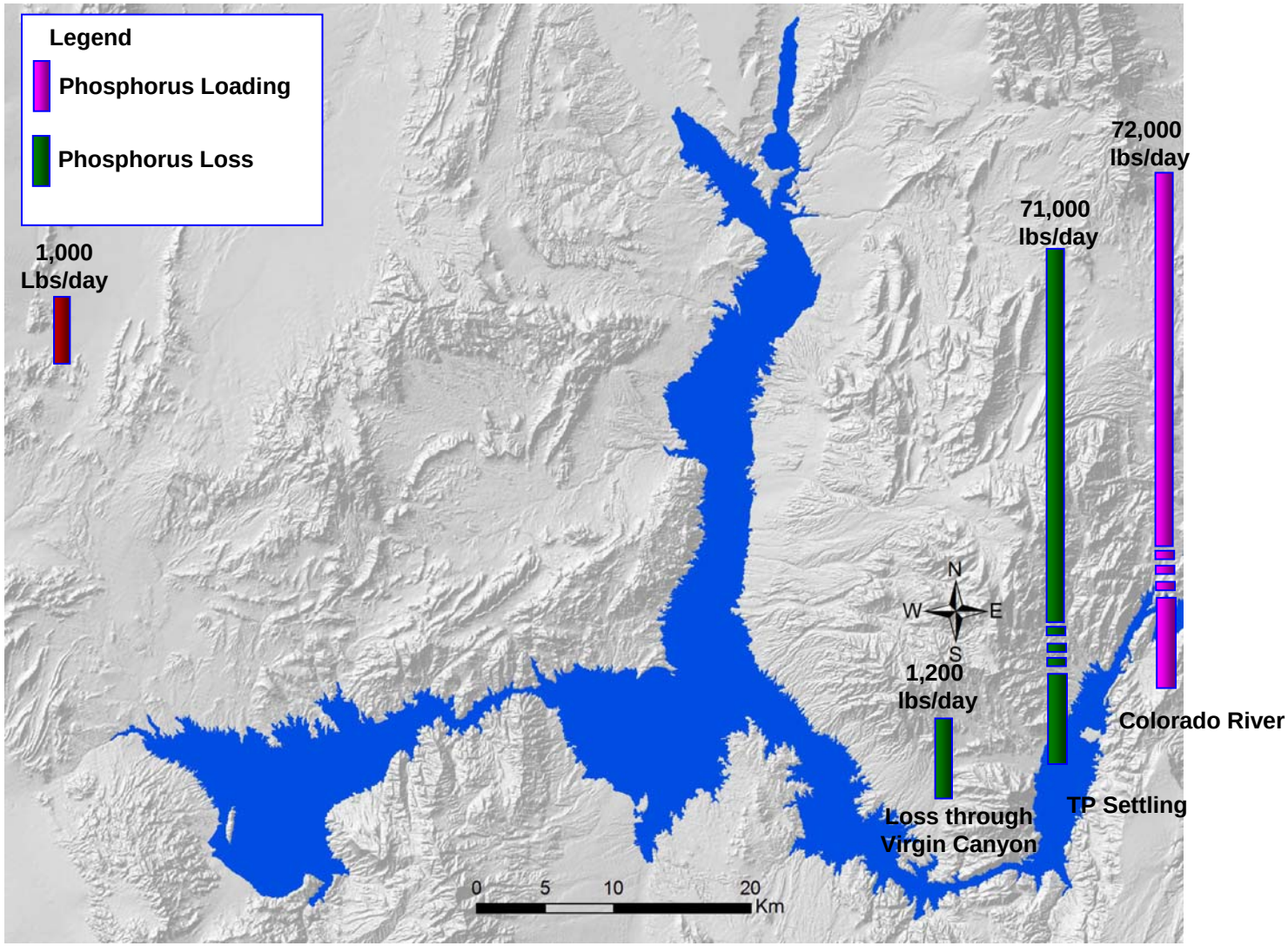
Calculation of Phosphorus Budget in Gregg Basin

- *CR Flow rate from USGS Station 09404200*
- *TP data measured at CRLM_B by USBR*
- *Flow rates through the Virgin Canyon were derived as follows*
  - *Vertical flow distribution used in FSI Boulder Basin Model was adopted in the calculation of TP flux at Virgin Canyon (see the following slide): 19% of flow through top 45 m; 66% of flow through the layer between 45 m and 100 m depth; 15% of flow through the layer below 100 m.*
- *TP data measured at CR390.0 by USBR were used in the calculation of TP mass flux through Virgin Canyon (in general, only TP measurements with the detection limit below 0.002 mg/L were considered)*
- *TP measurements at CR394.0 by USBR were used to estimate the reduction of TP stored in the water body of the Gregg Basin.*

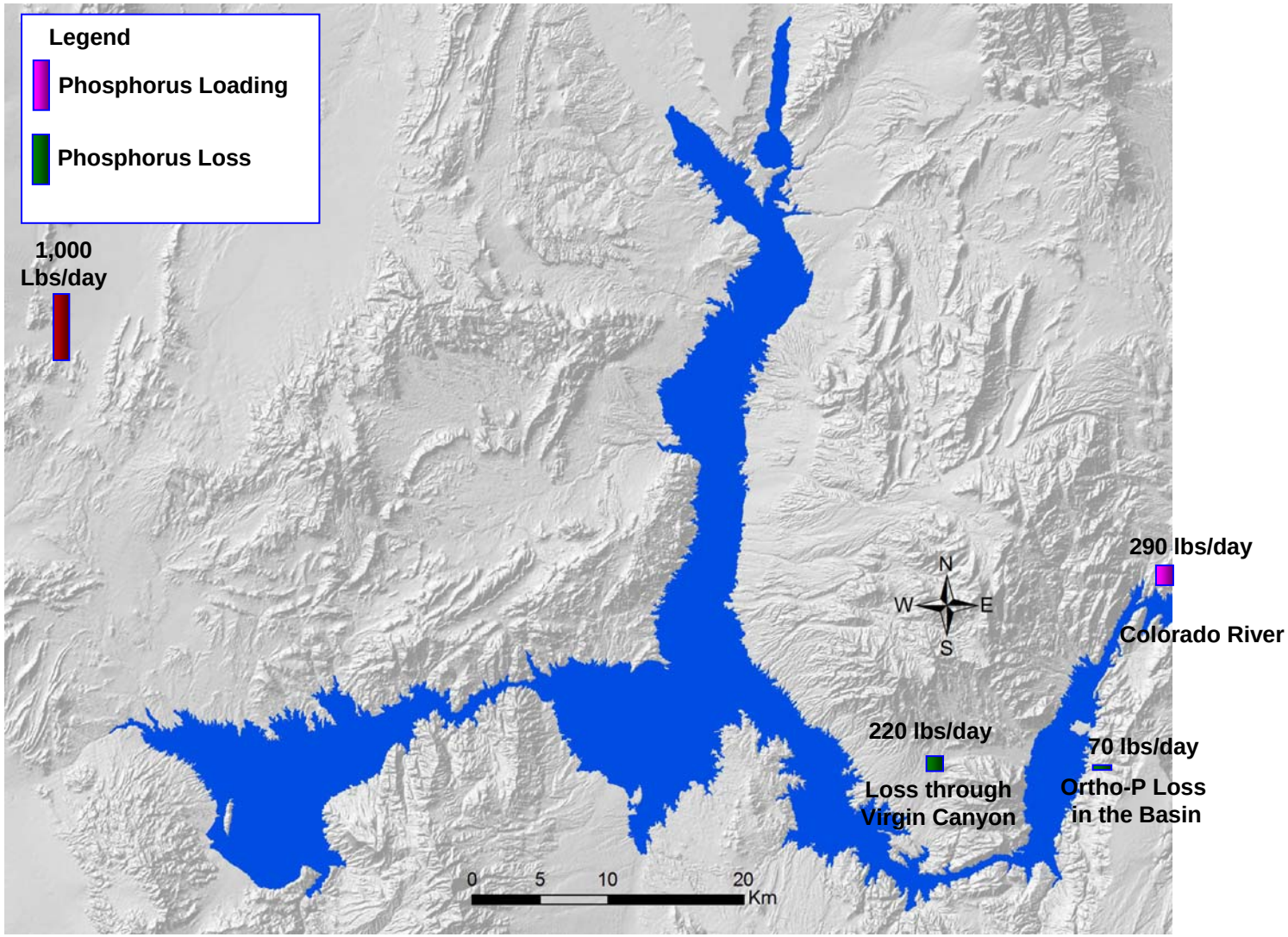
Vertical Distribution of the Flow in the Calculation of TP Loadings at Narrows and Virgin Canyon



2007 Total Phosphorus Budget in the Gregg Basin



2007 Ortho-Phosphate Budget in the Gregg Basin



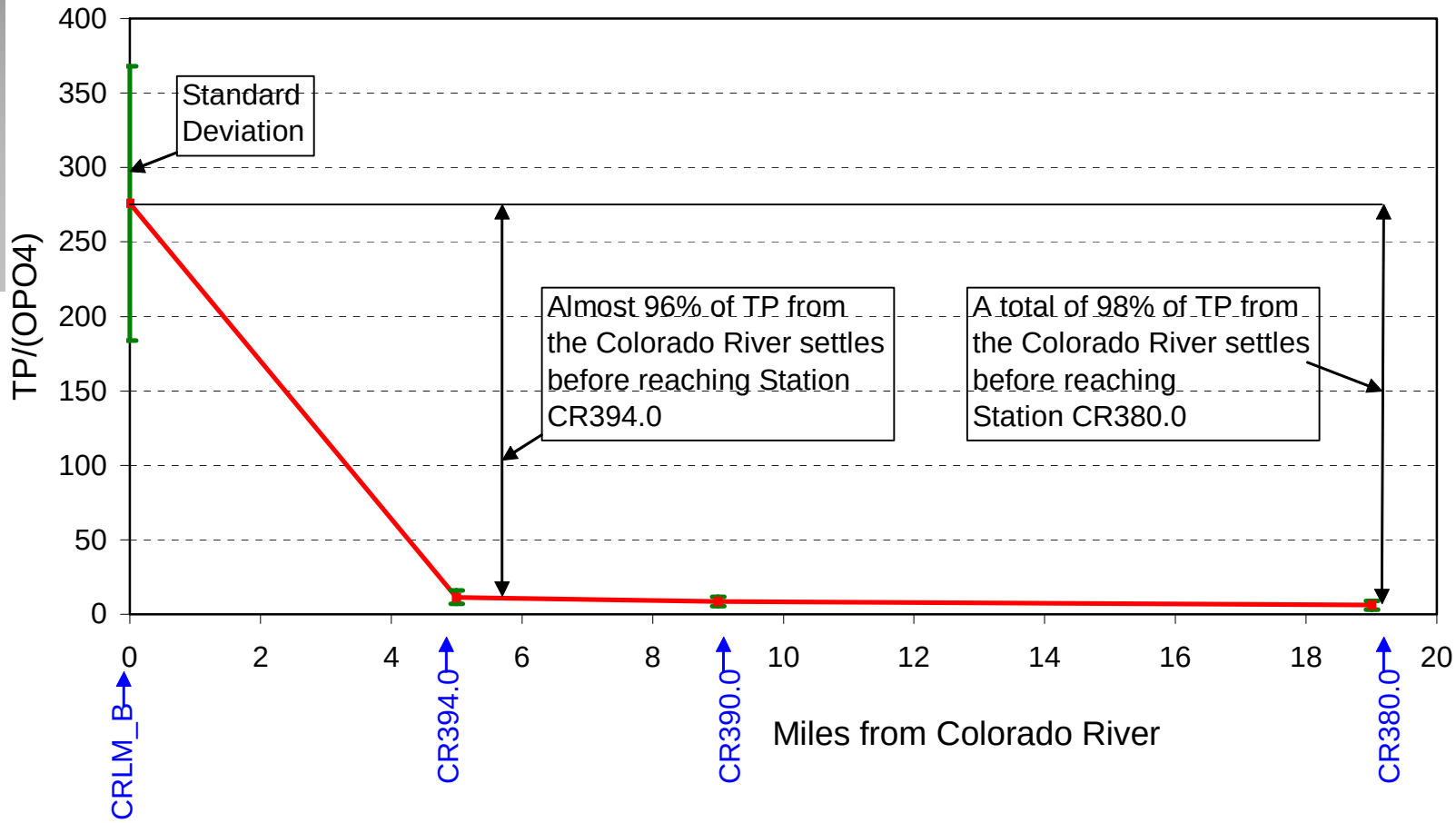
Settling of TP from Colorado River

Settling of TP from Colorado River – Studying the Ratio of TP to OPO4

- *Under the assumption of minimal loss of OPO4 to the algal consumption during the winter month at Lake Mead, the ratio of TP to OPO4 from Colorado River during the winter months should be more or less a constant in Gregg Basin without settling of TP particles because both TP and OPO4 from the Colorado River experience the same (but really small) dilution in the Gregg Basin.*
- *The reduction of the ratio of TP to OPO4 indicates the loss of TP due to the settling.*
- *By comparing the ratio among different stations, the percentage of TP from Colorado River that settles in the Gregg Basin can be estimated.*
- *The ratio of TP to OPO4 were averaged over the water columns. Only TP data with the TP and OPO4 detection limit below 0.002 mg/L were considered. The winter months at Lake Mead are defined as the months of November, December, January and February.*

The ratio of TP to OPO4 vesus Distance from the Colorado River

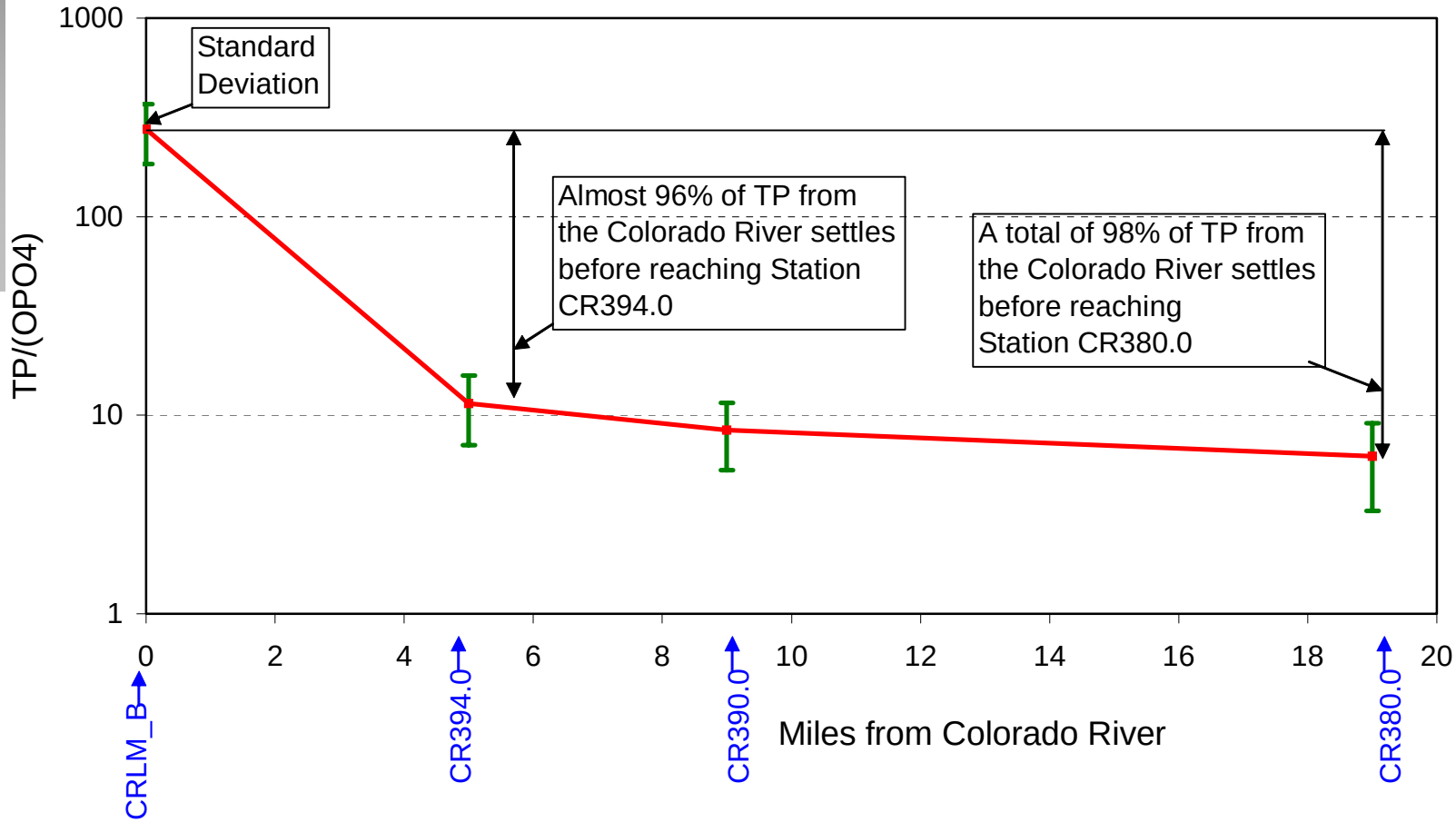
(Data between Nov 1 - Feb 28 were used, all data were from USBR)



** Notes: the calculation used data after 2007 when the detection limit decreases to 0.001 mg/L

The ratio of TP to OPO4 vesus Distance from the Colorado River

(Data between Nov 1 - Feb 28 were used, all data were from USBR)

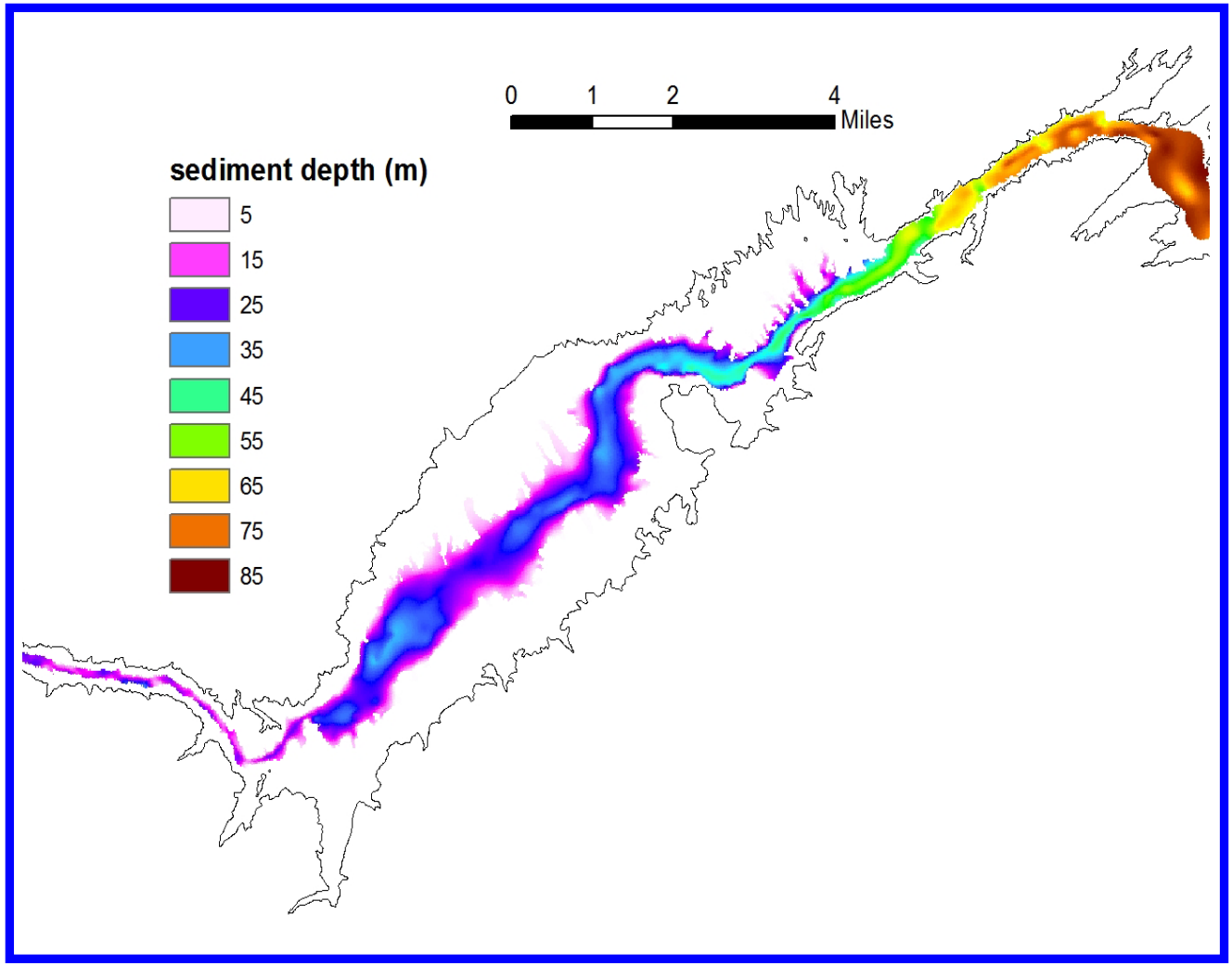


** Notes: the calculation used data after 2007 when the detection limit decreases to 0.001 mg/L

TP Settling in the Gregg Basin

- *Both the TP mass balance in the Gregg Basin and reduction of the ratio of TP to OPO4 from the Colorado River to the Basin indicate that over 96% of TP loadings from the Colorado River settles in the Gregg Basin.*
- *The sediment depth survey in the Gregg Basin shown on the next slide confirms that there is significant sediment accumulation in the Gregg Basin. The sharp gradient of the sediment depth between the mouth of the River and the middle of the Basin indicates that a large portion of these particles settles in the first few miles into the Basin. This is consistent with our findings here.*
- *The ratio of TP/OPO4 is fairly high at Colorado River (~270) while is only about 2.7 at Las Vegas Wash. This implies that Colorado River carries large portion of particular form of TP that can easily settle while TP from LVW does not settle very much.*

Sediment Depth in the Gregg Basin



Phosphorus Budget in the Virgin and Temple Basins and Overton Arm

Calculation of Phosphorus Budget in Virgin Basin and Overton Arm

- *TP data measured at CR390.0 by USBR were used for input from CR*
- *Flow rate measured at USGS Station 09415250 are available after 4/21/2006 and were used for the inflow from the Virgin River.*
- *TP data measured at VR49.3 by SNWA were used for TP loadings from the Virgin River.*
- *TP data measured at MR8.0 by SNWA were used for TP loadings from the Muddy River.*
- *Water flow rates through The Narrows were derived using the mass balance based on the inflow from the Gregg Basin, lake levels and average evaporation rate.*
- *TP data measured at CR360.7 by USBR were used for TP mass flux through The Narrows.*
- *Vertical flow distribution used in FSI Boulder Basin Model was adopted in the calculation of TP flux at Virgin Canyon TP measurements at VR2.0 by SNWA were used to estimate the reduction of TP stored in the water body of the Virgin Basin.*

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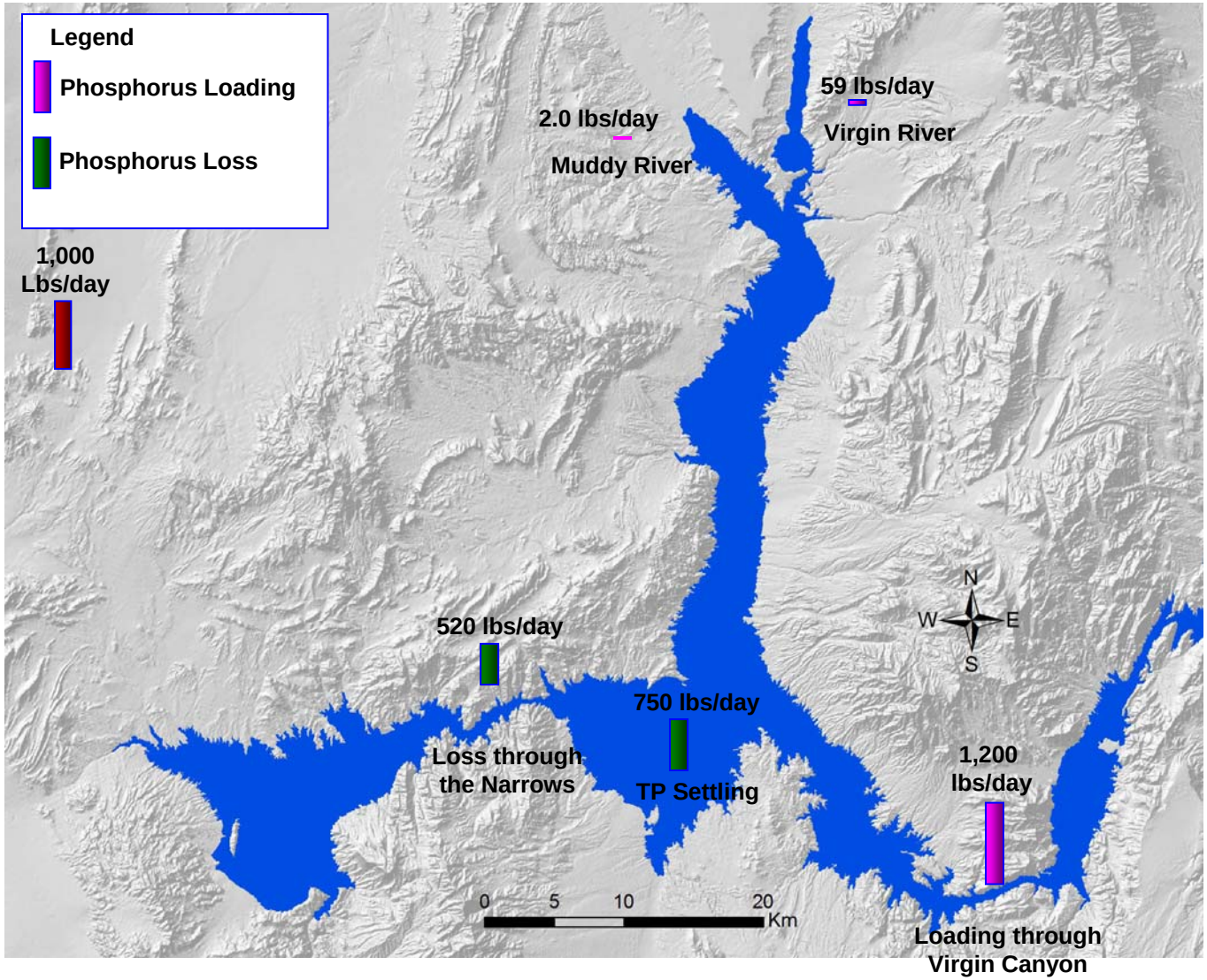
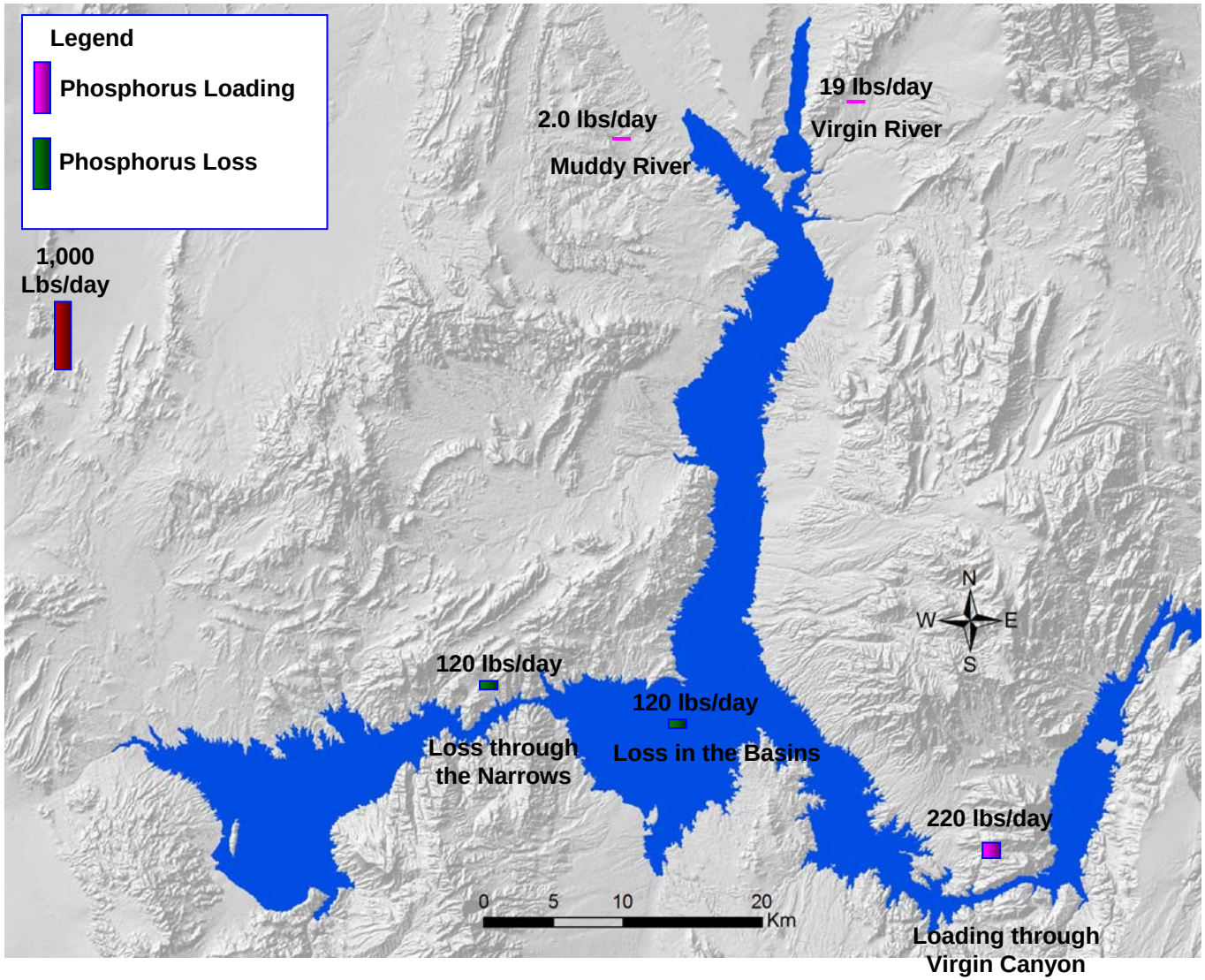
2007 Total Phosphorus Budget in the Virgin and Temple Basins and Overton Arm



2007 Ortho-Phosphate Budget in the Virgin and Temple Basins and Overton Arm

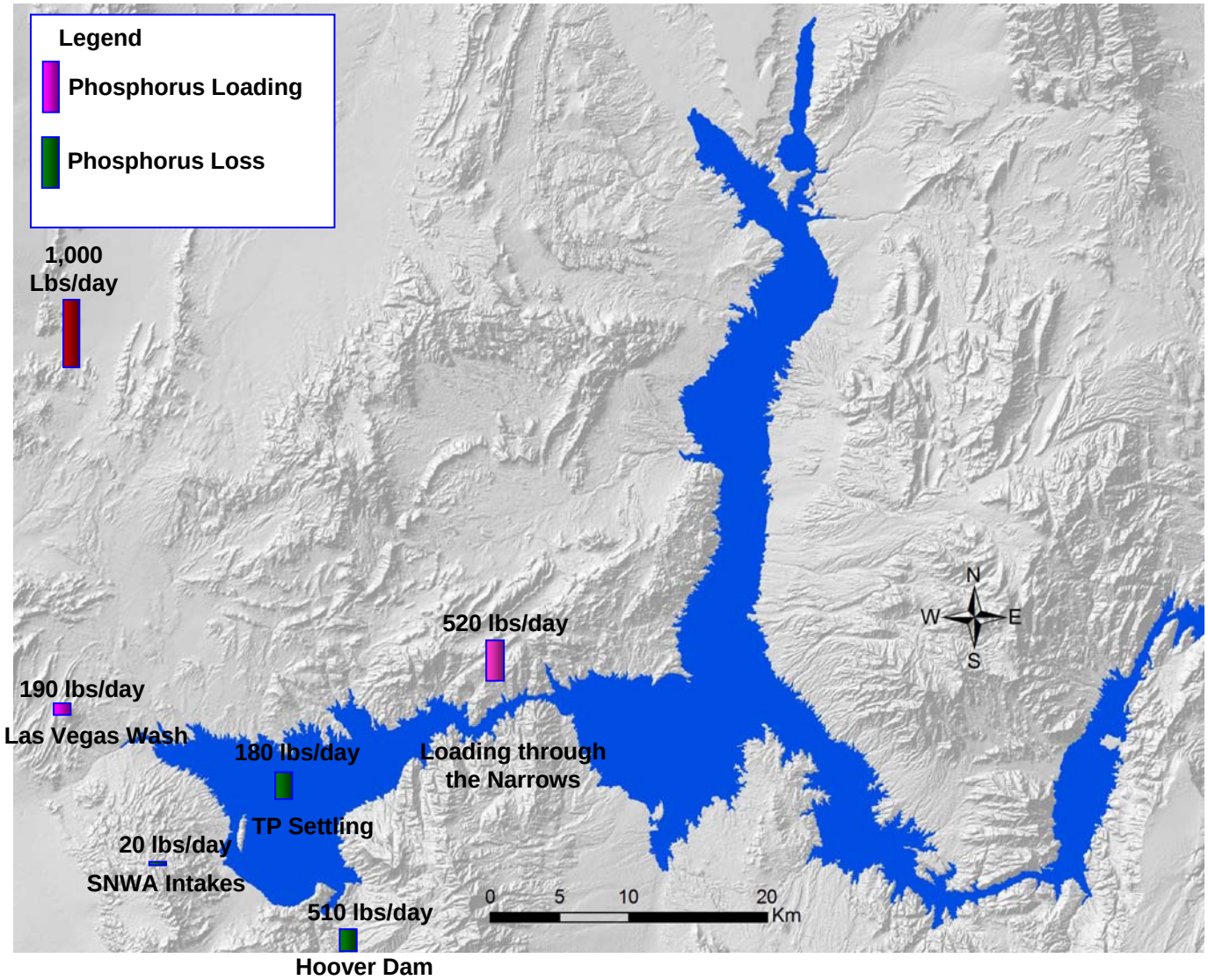


Phosphorus Budget in the Boulder Basin

Calculation of Phosphorus Budget in Boulder Basin

- *TP data measured at CR360.7 by USBR were used in the calculation of TP mass flux through The Narrows.*
- *Flow rate data (USGS 09419790 through 6/30/02 and 09419800 from 7/1/02 onwards) were used for Las Vegas Wash Inflow*
- *TP data measured at Station LW0.55 by City of Henderson were used for the TP concentrations from the LVW.*
- *Both flow rates and TP data at the SNWA intakes were from SNWA*
- *Flow rates through Hoover Dam Outlets were obtained from USGS*
- *TP data measured by SNWA at Station CR342.0 were used as TP concentrations for the water through Hoover Dam Outlets. Also these were compared to USGS data. This is a new update since the draft report was sent out.*
- *TP measurements at CR346.4 by USBR were used to estimate the reduction of TP stored in the water body of the Boulder Basin.*

2007 Total Phosphorus Budget in the Boulder Basin



TP Loadings from the Las Vegas Wash

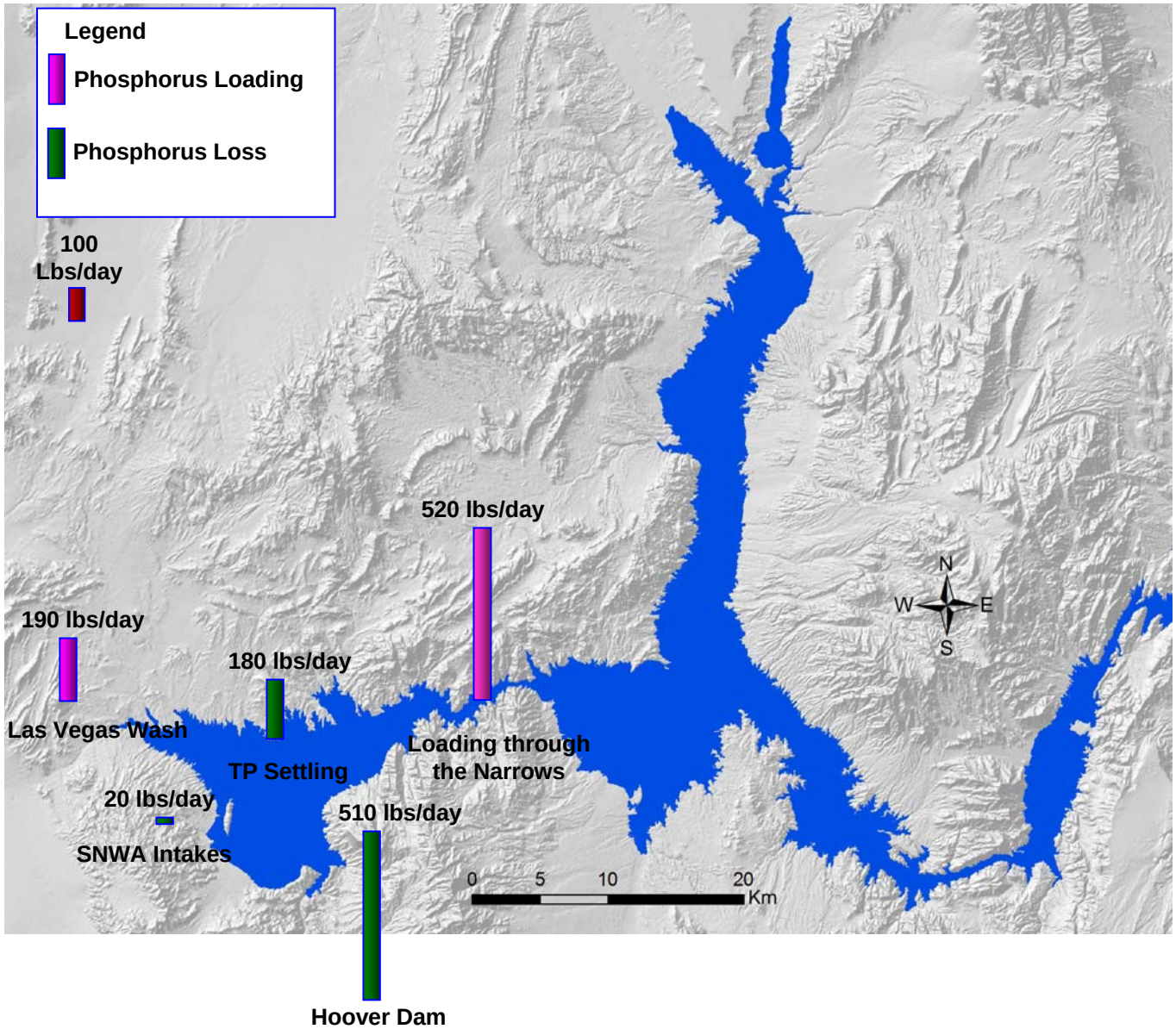
Phosphorus Loadings and Concentrations using Data at LW0.55

Year	Annual Average Flow Rate (cfs)	Annual Average TP		Annual Average Ortho-P	
		Concentration (mg/L)	Loading (lbs/day)	Concentration (mg/L)	Loading (lbs/day)
2000	220	0.34	440	0.21	260
2001	240	0.23	320	0.15	200
2002	250	0.22	310	0.13	180
2003	270	0.21	310	0.099	140
2004	280	0.17	270	0.075	120
2005	300	0.12	220	0.048	80
2006	300	0.12	200	0.067	110
2007	290	0.12	190	0.082	130

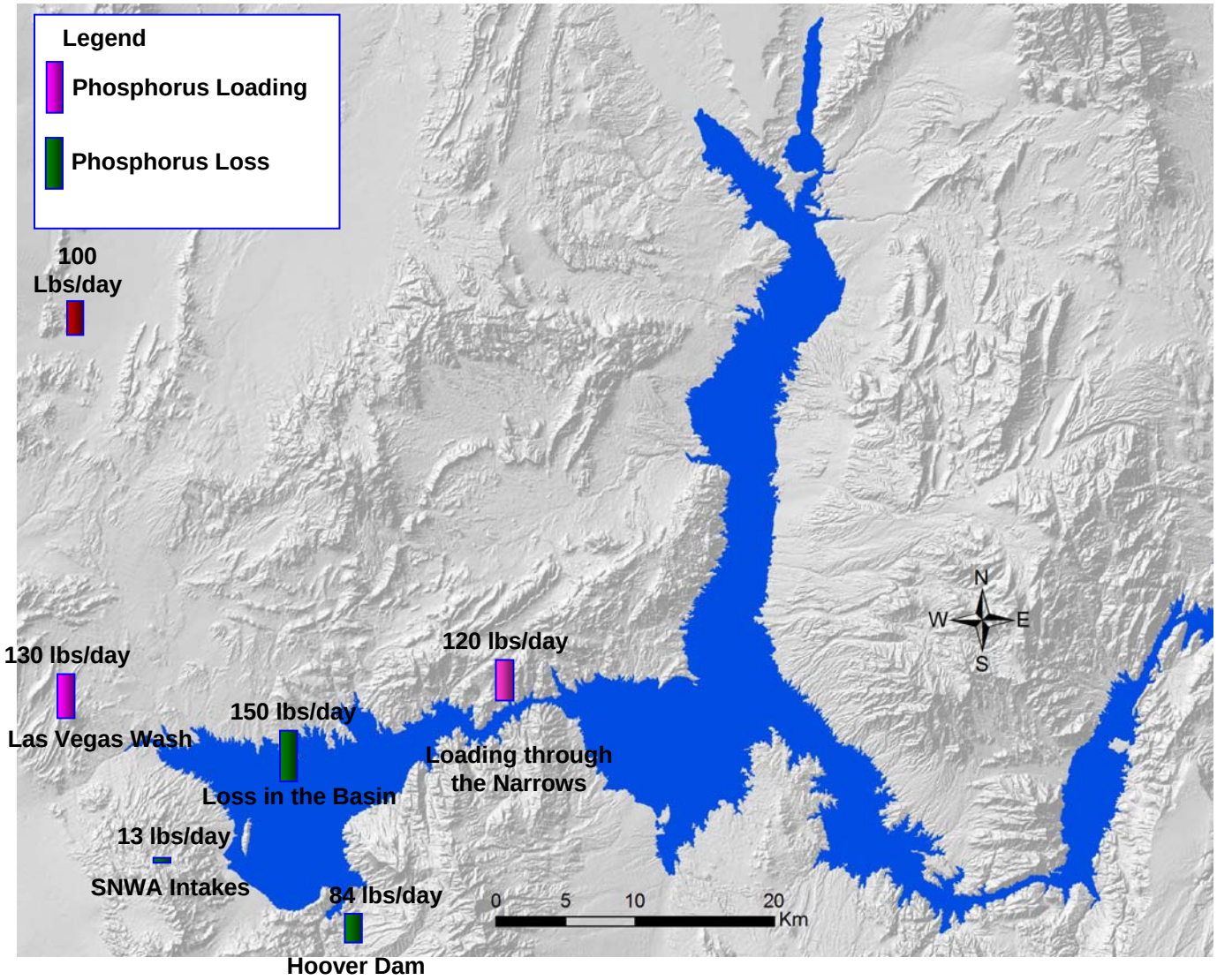
Phosphorus Loadings and Concentrations from WWTPs

Year	Annual Average Flow Rate (MGD)	Annual Average TP		Annual Average Ortho-P	
		Flow Weighted Concentration (mg/L)	Loading (lbs/day)	Flow Weighted Concentration (mg/L)	Loading (lbs/day)
2000	140	0.34	390	0.28	310
2001	140	0.30	340	0.23	260
2002	130	0.25	280	0.19	220
2003	140	0.21	260	0.16	190
2004	150	0.17	220	0.11	140
2005	160	0.13	170	0.072	98
2006	160	0.16	210	0.10	140
2007	160	0.15	200	0.092	120

2007 Total Phosphorus Budget in the Boulder Basin



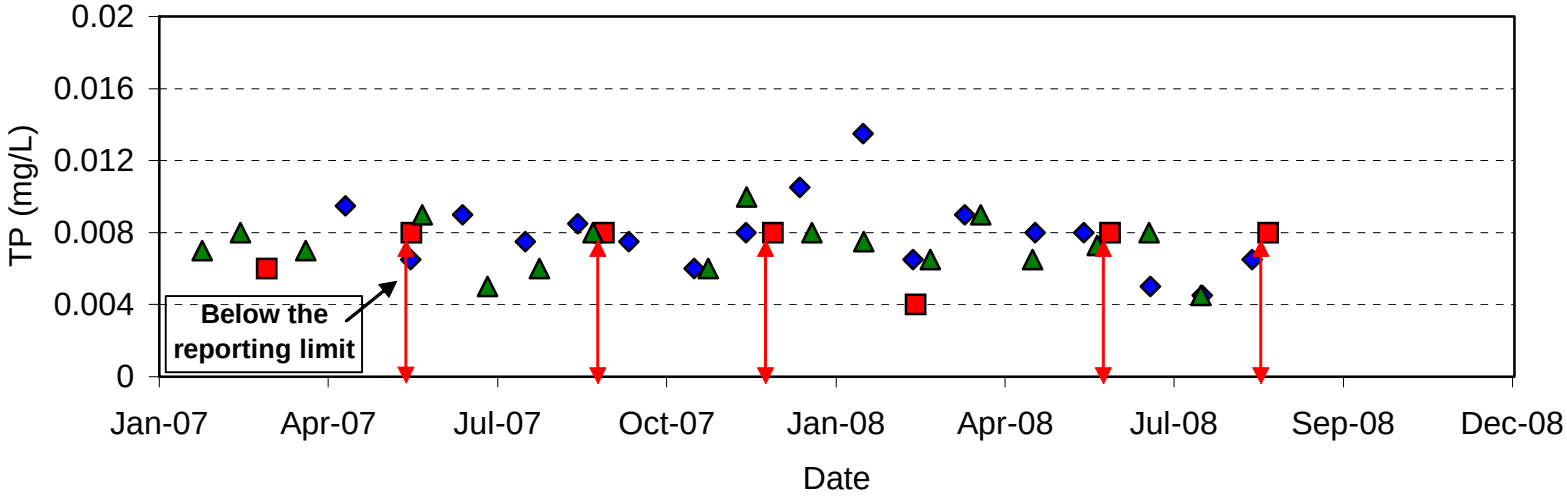
2007 Ortho-Phosphorus Budget in the Boulder Basin



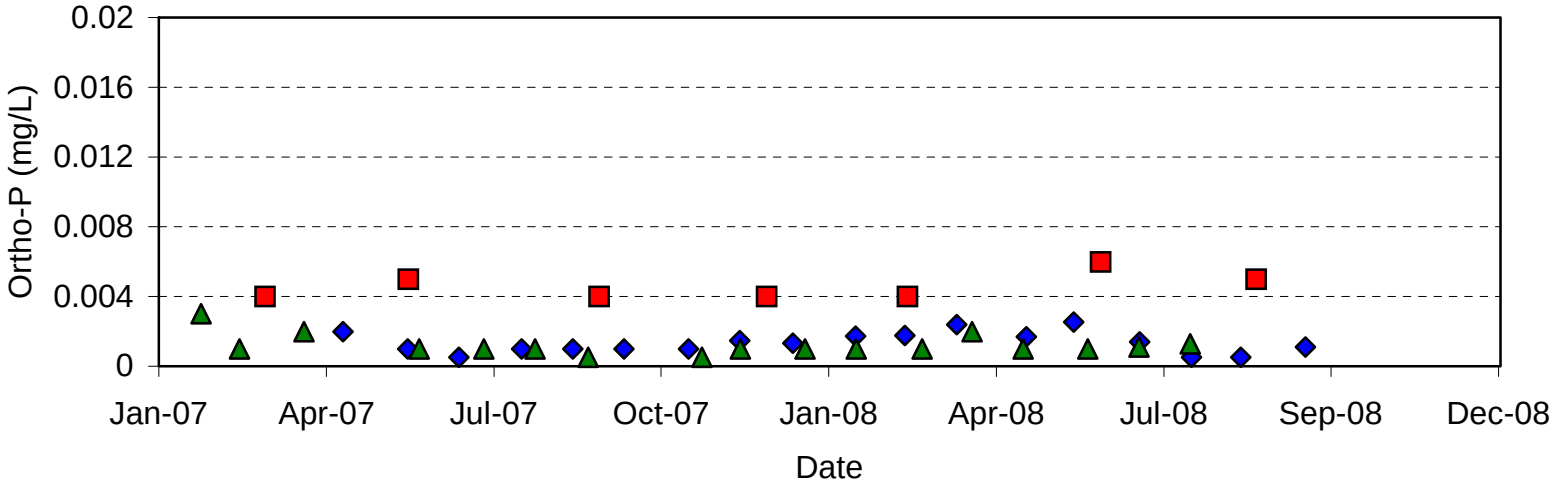
Comparison of 2007 Phosphorus Data at Hoover Dam

(Data shown here are average of data at the upper and lower outlets)

Total Phosphorus



Ortho-Phosphate



Impacts on Phosphorus Budget by Using P Data from Different Sources

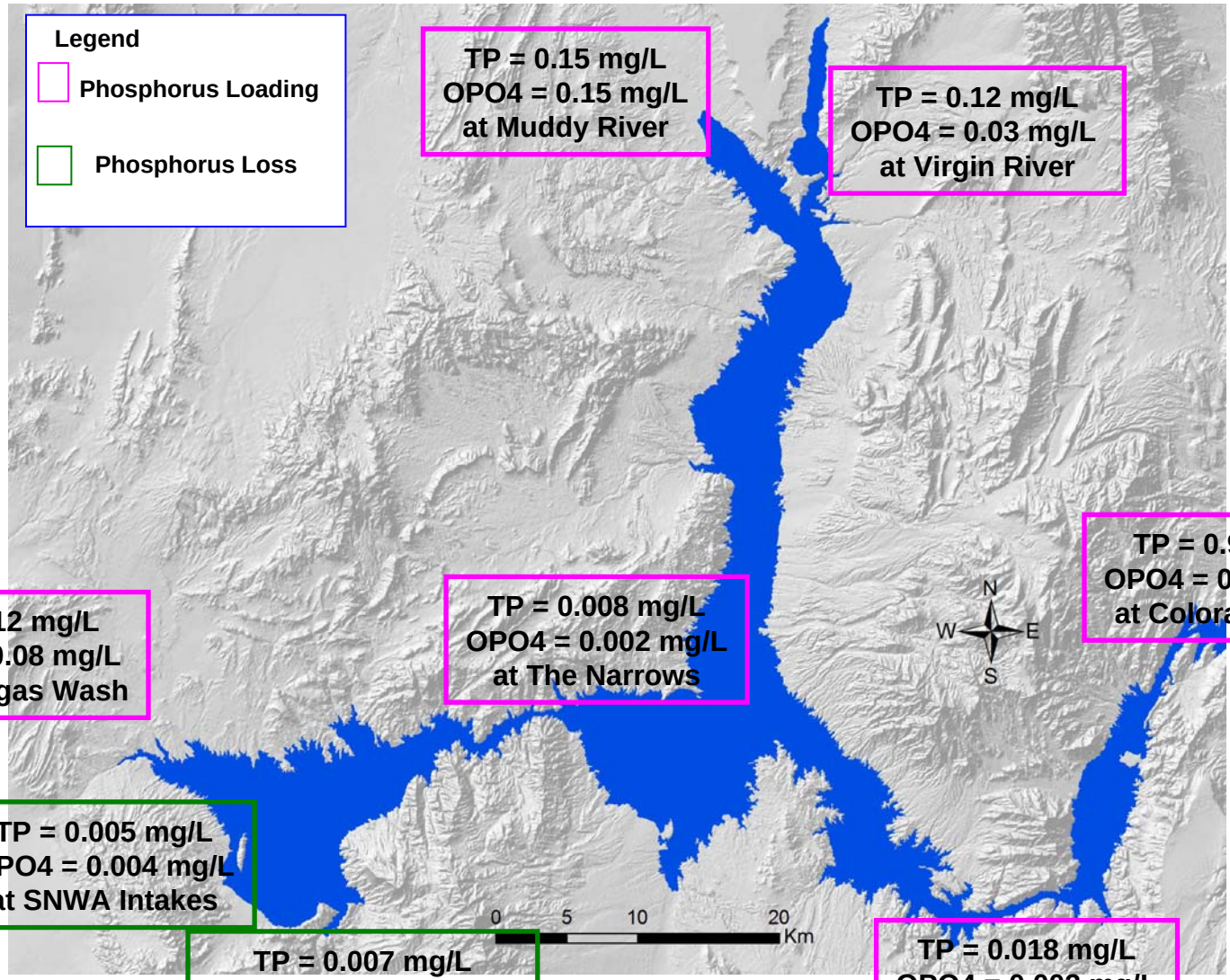
2007 Total Phosphorus Balance in the Boulder Basin

Data Sources at Hoover Dam	TP mass loadings from LVW (lbs/day)	TP mass loadings through The Narrows (lbs/day)	TP mass withdrawn from the SNWA Intakes (lbs/day)	TP mass withdrawn through the Hoover Dam (lbs/day)	Reduction in TP stored in the water body of the Boulder Basin (lbs/day)	Loss or settling in the Boulder Basin (lbs/day)
SNWA	190	520	-20	-510	-1	180
USGS	190	520	-20	-310	-1	380
USBR	190	520	-20	-530	-1	170

2007 Ortho-Phosphorus Balance in the Boulder Basin

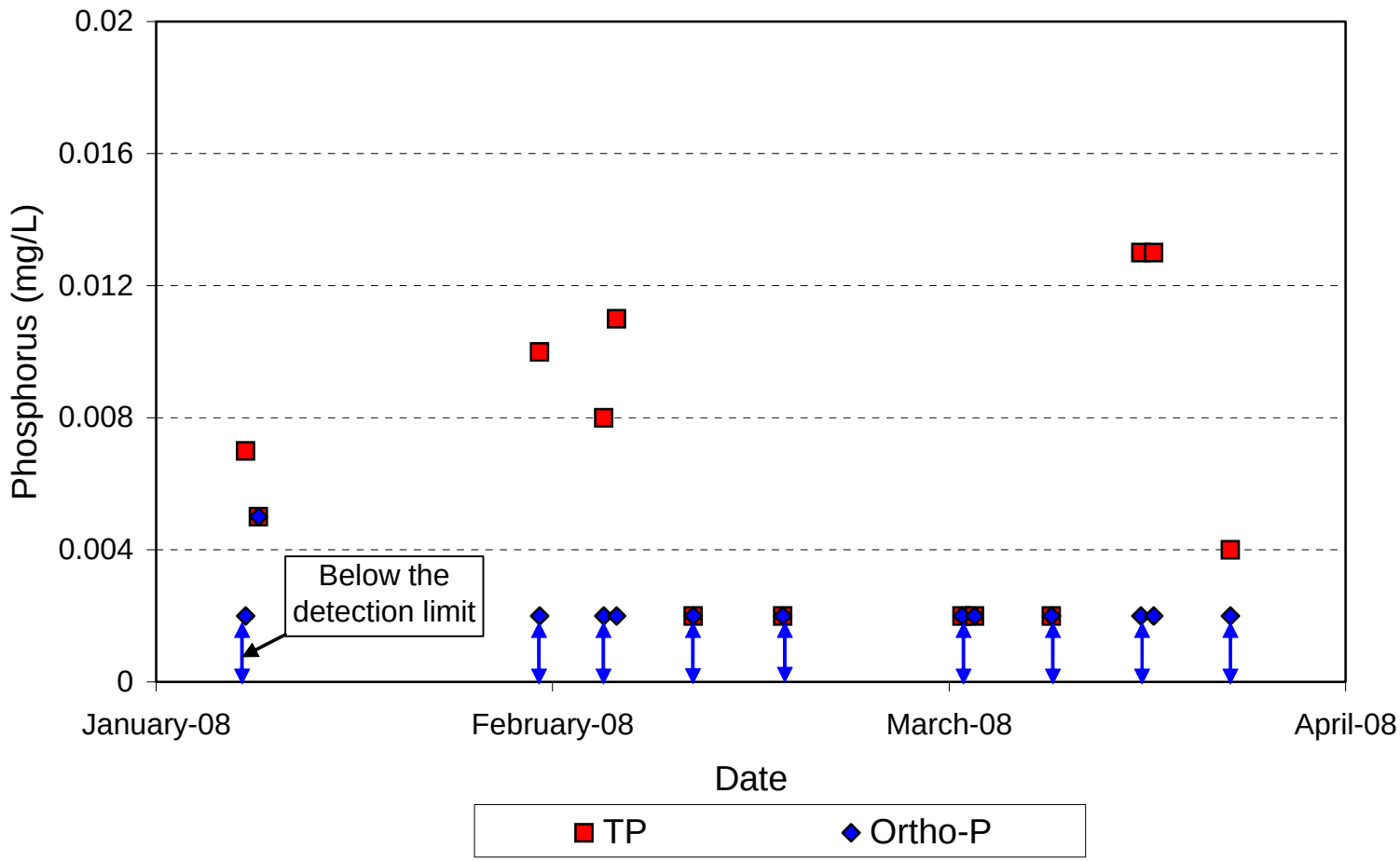
Year	Ortho-P mass loadings from LVW (lbs/day)	Ortho-P mass loadings through The Narrows (lbs/day)	Ortho-P mass withdrawn from the SNWA Intakes (lbs/day)	Ortho-P mass withdrawn through the Hoover Dam (lbs/day)	Reduction in Ortho-P stored in the water body of the Boulder Basin (lbs/day)	Loss in the Boulder Basin (lbs/day)
SNWA	130	120	-13	-84	1	150
USGS	130	120	-13	-280	1	-42
USBR	130	120	-13	-90	1	150

2007 Average Phosphorus Concentrations in the Lake Mead



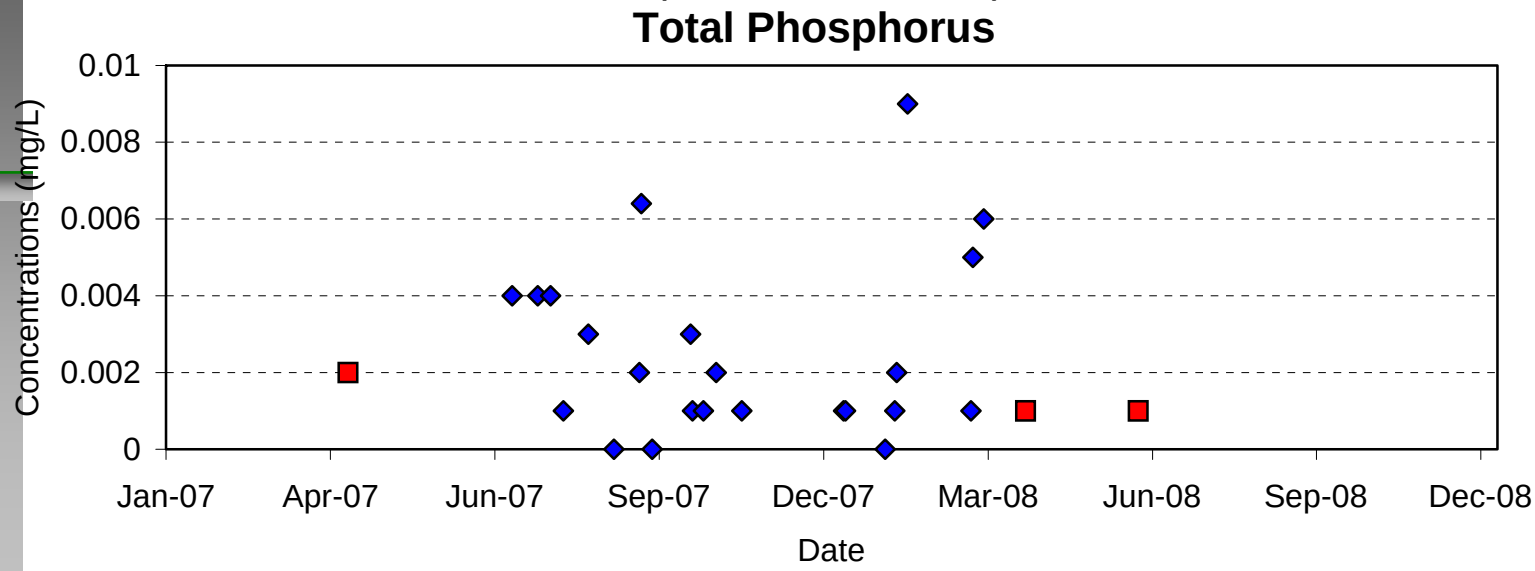
Comparison of Phosphorus Concentrations Measured by Different Agencies

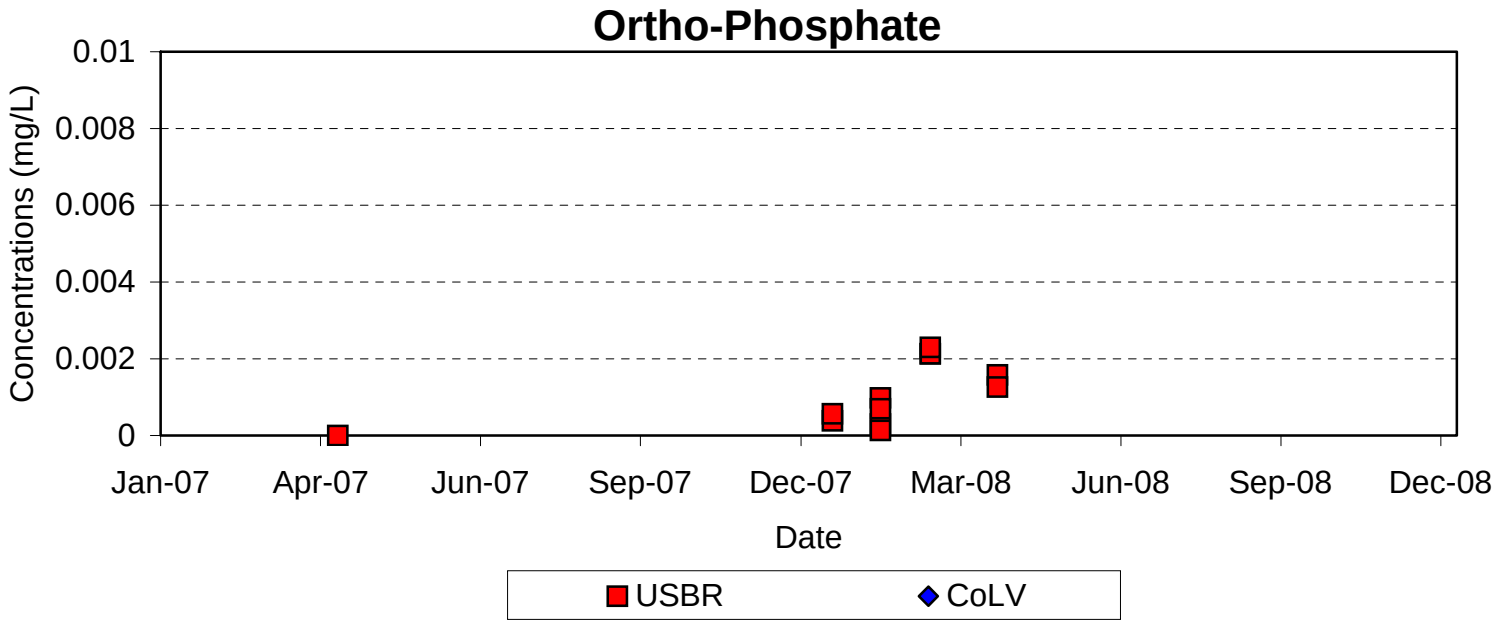
Phosphorus Concentrations of Blank Samples in CoLV Data Set



Absolute Difference of Duplicate Samples from USBR and CoLV Data

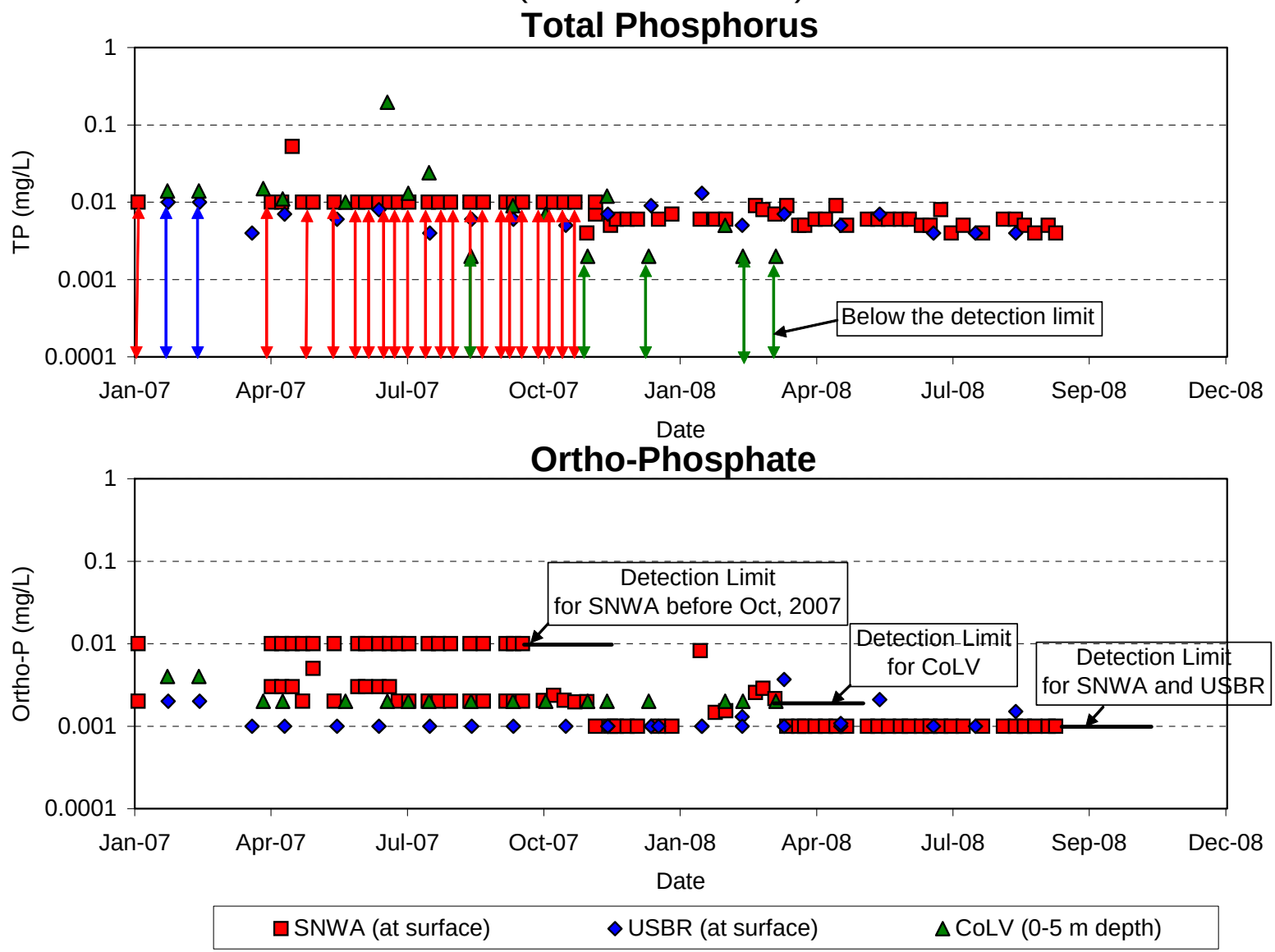
(Station: CR346.4)





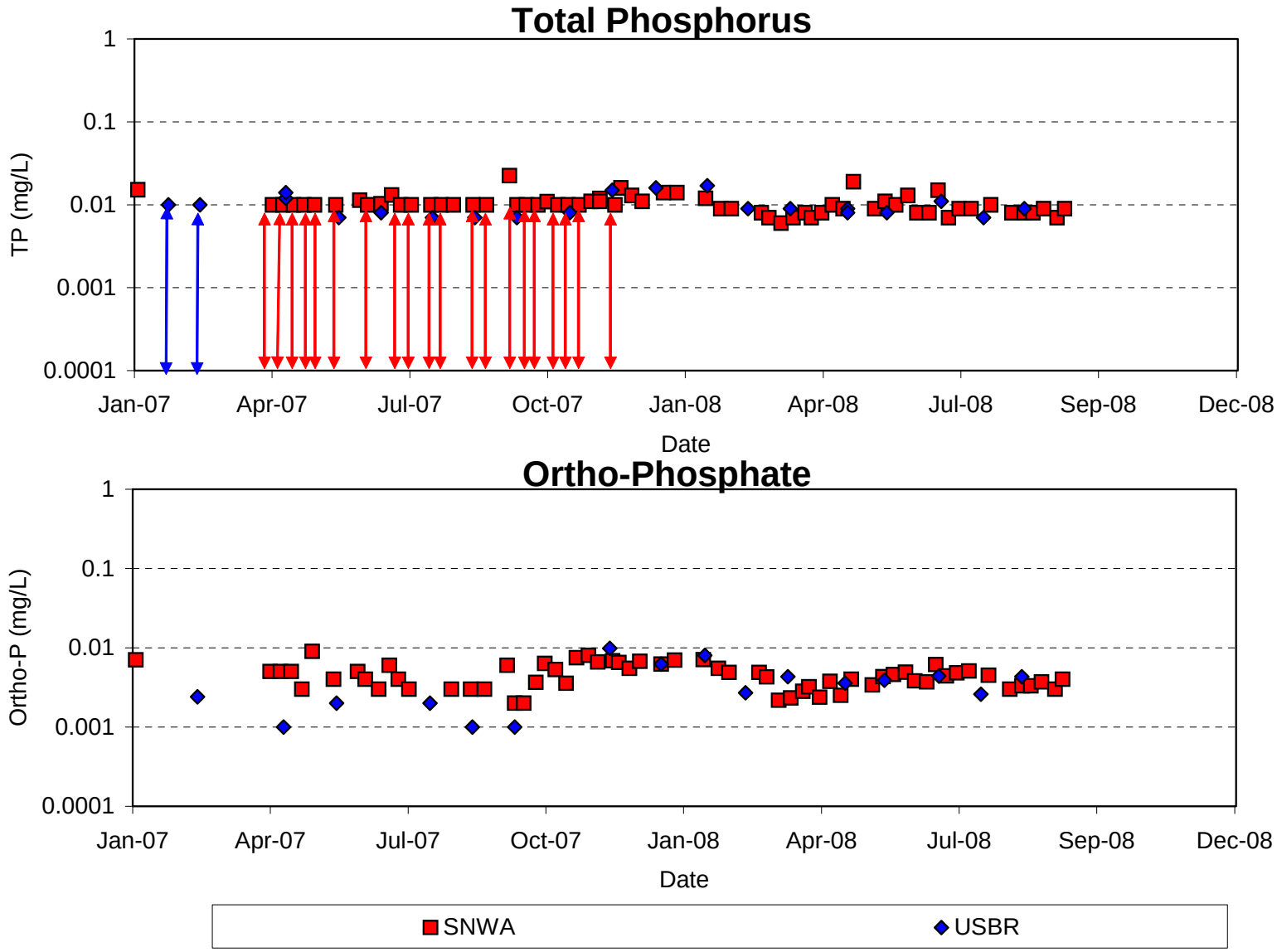
Comparison of Near-Surface Phosphorus Data from USBR and CoLV Data

(Station: CR346.4)



Comparison of Near-Bottom Phosphorus Data from USBR and CoLV Data

(Station: CR346.4)



Conclusion (I)

- *The detection limit for in-lake TP data was generally about 0.01 mg/L prior to 2007. That can result in an error of 670 lbs/day in the calculation of TP Loadings. Meaningful phosphorus budget cannot be determined prior to 2007.*
- *Phosphorus budgets developed here reveal that a significant portion of TP loading from the Colorado River is in particulate form and quickly settles in the Gregg Basin. Less than 1% of the TP loading from the Colorado River reaches the Boulder Basin through The Narrows. The loading from Las Vegas Wash accounts for 50% of total Ortho-P loading and 30% of total TP loading for the Boulder Basin.*

Conclusion (II)

- *At Hoover Dam, phosphorus data from USBR and SNWA are reasonably matched, but USGS data are different from USBR and SNWA data. This will have great impacts on the calculation of the TP balance in the Lake. For example, the TP mass withdrawn out of the Hoover Dam can be 510 lbs/day if SNWA data are used, 530 lbs/day if USBR data are used, or 310 lbs/day if USBR data are used.*
- *A ratio of TP to Ortho-P during the winter months was used to illustrate that 96% of TP loading from the Colorado River settles within 6 miles (9.6 km) from the mouth of the river. As sediment depth survey in the Gregg Basin shows a significant sediment accumulation in the region close to the mouth of the river and this is consistent with the findings of the analysis presented here.*

Conclusion (III)

- *The accuracy of the ortho-phosphorus data is generally better than that of the TP data, based on the results of blank and duplicate samples reported by USBR and CoLV. At Station CR346.4, phosphorus data from USBR and SNWA are reasonably matched, but CoLV data show more deviation from the USBR and SNWA data.*
- *Although the detection limit has been significantly improved since 2007 (0.01 mg/L → 0.001 m/L for TP; 0.002 mg/L → 0.001 mg/L for Ortho-P), an even lower detection limit is still desirable because an error of 0.001 mg/L in phosphorus concentration can produce an error of 70 lbs/day in the phosphorus loading at the Colorado River, Hoover Dam and the Narrows etc. and this error can skew the results for internal source/sink by as much as 100%.*
- *Moreover, further efforts are needed to reduce errors for blank samples and improve reproducibility of the phosphorus data. An approach, where the various agencies take samples at the same location and time and compare the phosphorus results, is worth pursuing in order to fully estimate the inter-agency data error.*

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