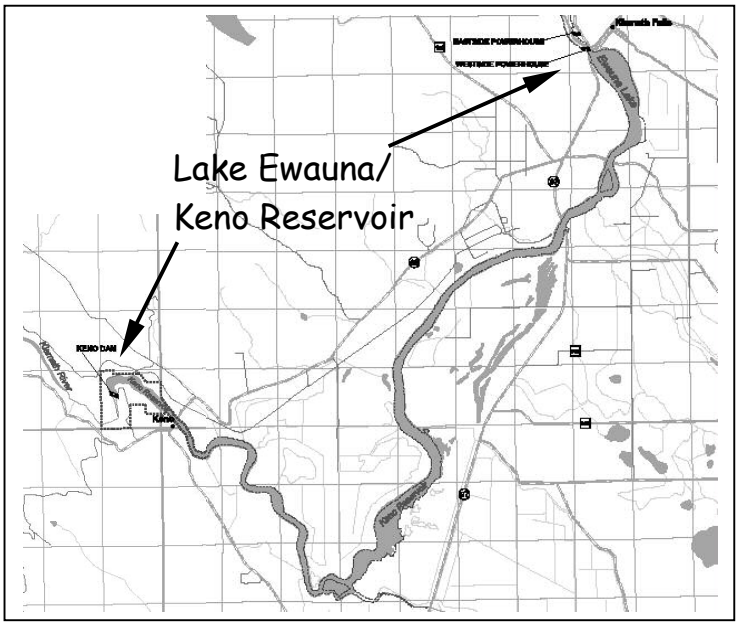
2. Lake Ewauna / Keno Reservoir

Reach Location and Characteristics

Lake Ewauna / Keno reservoir (LEKR) are formed by Keno Dam on the Klamath River at approximately RM 233. Lake Ewauna proper is a wide, relatively shallow body of water from about RM 251 to 253, while Keno reservoir is a narrower reach between RM 233 and 251. The impoundment, formed in 1967, is approximately 20 miles in length.



Lake Ewauna / Keno Reservoir Physical and Operational Characteristics			
Impoundment length (miles)	20.1	Normal full pool elevation (ft msl)	4085
Impoundment length (RM)	233-253.1	Normal minimum pool elevation (ft msl)	NA
Surface area (acres)	2,475	Normal annual operating fluctuation (ft)	2.0
Maximum / mean depth (ft)	20 / 7.5	Average daily operating fluctuation (ft)	0.5
Total storage capacity (ac-ft)	18,500	Normal active storage capacity (ac-ft)	2,475 (est.)
Total retention time (days)		Active storage retention time (days)	
At 710 cfs	13	At 710 cfs	1.7
At 1600 cfs (□mean flow)	6	At 1600 cfs (□mean flow)	0.8
At 10,000 cfs (extreme event)	1	At 10,000 cfs (extreme event)	0.1

Dam Characteristics and Flow Control Structures

- Keno dam characteristics are listed in the adjacent table.
- There is no hydropower diversion from this reservoir. Numerous diversion and inputs for agricultural, municipal, and industrial purposes.

Keno Dam Characteristics	
Dam type: *Concrete*	
Dam overall length (ft)	680
Dam crest elevation (ft msl)	4091
Dam height (ft)	26
Spillway type: *Ogee with 6 radial gates*	
Spillway length (ft)	265
Spillway crest elevation (ft msl)	4070
Diversion intake type: *No Project diversion*	

- Keno dam is equipped with a pool and weir fish ladder.
- PacifiCorp has a cooperative agreement with ODFW for a minimum instream flow release of 200 cfs from Keno dam.

Operations

- Keno is a re-regulating facility with no generating capability. The Keno facility is operated as a diversion dam to control Keno reservoir for agricultural diversions by the USBR's Klamath Irrigation Project. PacifiCorp built the facility with the intent to produce power, but hydropower facilities were never developed.

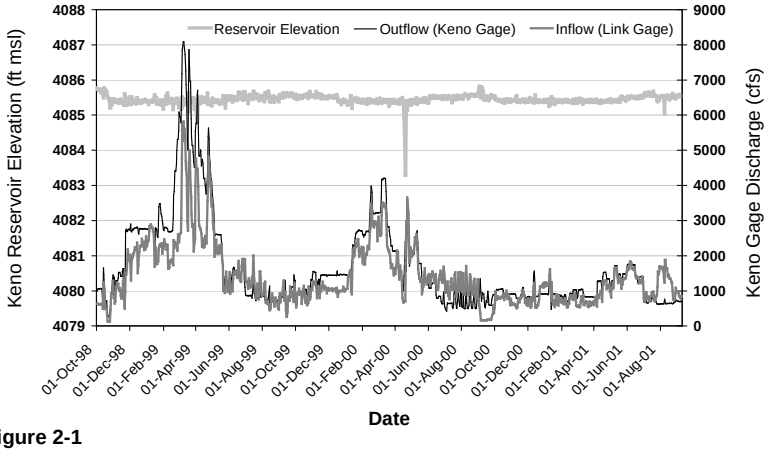


Figure 2-1
Daily Average Keno Reservoir Elevation and Estimated Reservoir Inflow and Outflow for WYs 1999-2001

- The Keno facility is operated to maintain Keno reservoir at an approximately constant elevation. Reservoir levels rarely fluctuate more than 0.5 ft seasonally (Figure 2-1). The reservoir may be drawn down a few feet for 1-2 days each year to allow irrigators to access pumps and canals for maintenance.
- Because of relatively small active storage, Keno reservoir has a modest effect on the general shape and trend of annual hydrograph (Figure 2-1). However, the effects of inflow and flow diversions are evident at specific times and days.
- Inflows within the LEKR reach include releases from Upper Klamath Lake, municipal wastewater discharges, industrial discharges, agricultural return flow, as well as natural inflow from adjacent areas (Figure 2-2, Table 2-1). The principal agricultural discharge is the Klamath Straits drain; however other return flow points occur within this reach. Principal diversions include the Lost River Diversion Canal, North Canal, and ADY Canal. The Lost River Diversion Canal can discharge water to the Klamath River as well.
- Link River inflow makes up just under 80 percent of the total inflow and agricultural returns about 20 percent. Municipal and industrial inflows are about one percent. Of course, these quantities may vary widely on a day-to-day or week-to-week basis.

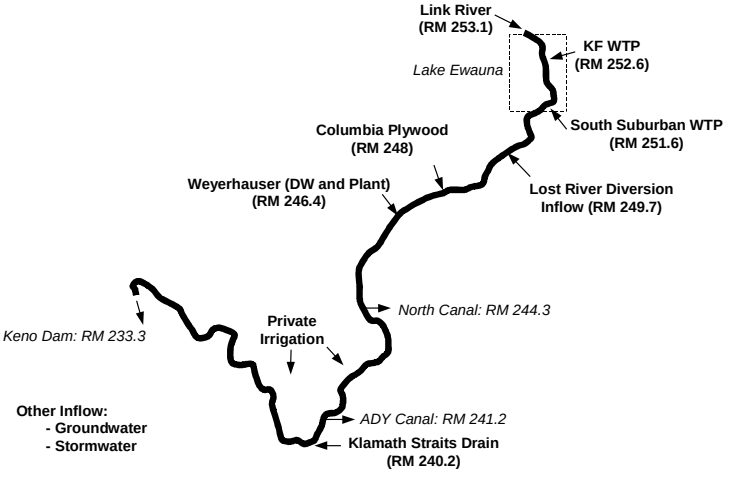


Figure 2-2
Lake Ewauna / Keno Reservoir Inflow Locations

- Municipal and industrial discharges are localized between RM 246.6 and RM 252.4. These discharges, although small in terms of quantity, may represent considerable mass loads to the system.
- Agricultural returns consist principally of two point sources: the Lost River Diversion Canal (249.7) and the Klamath Straits Drain (RM 240.2). The Lost River Diversion Canal discharges into the same reach that the municipal and industrial discharge occurs. Private irrigation return flow enters the system throughout the reach.
- The principal constraint imposed on the operation of the Keno facility is a minimum instream flow of 200 cfs below the dam (per cooperative agreement with ODFW). There are currently no stipulated limits on changes in flow rate (i.e., ramp rate).

Table 2-1
Lake Ewauna / Keno Reservoir Inflow Locations and Quantities

	RM	Representative Flow*	% of Total*
Link River	253.1	800	77.8%
KF WTP	252.6	4.5	0.4%
S. Suburban WTP	251.6	2.2	0.2%
Lost River Diversion Canal	249.7	100	9.7%
Columbia Plywood	248	n/a	-
Weyerhauser (Domestic and Plant)	246.4	2.0	0.2%
Klamath Straits Drain	240.2	120	11.7%
Private Irrigation	-	n/a	-
Groundwater	-	n/a	-
Stormwater	-	n/a	-
		1028.7	100%

Values adapted from: ODEQ (1995) *Water Quality Model of the Klamath River between Link River and Keno Dam (DRAFT)*. Prepared by CH2M HILL and S. Wells. December.

*Based on available flow data (i.e., not including private irrigation return, groundwater, and stormwater)

Limnological Description and Water Quality Trends

- The LEKR reach has relatively short flow retention rates (about 6 days at the average flow of 1600 cfs, and about 13 days at 700 cfs). Due to its short flow retention rates and rather narrow, channeled basin, Keno reservoir combines features of both riverine and lacustrine environments.
- The water quality in inflow sources to LEKR is summarized in Table 2-2. The water quality within LEKR is summarized in Table 2-3. The data, along with inflow amounts summarized in Table 2-1, suggest that LEKR is heavily loaded at the top (upstream) end of the system. This loading no doubt plays a role in the overall ability of the system to absorb and process mass loading.

Table 2-2
Lake Ewauna / Keno Reservoir Inflow Water Quality

Parameter	Units	Link R	KFWTP	SSWTP	LRDC	Weyer. Plant	Weyer. STP	KSD
BOD_u	mg/l	20-45	5-140	20-130	<3	5-60	5-60	10
CHl_a	ug/l	<1-450	-	-	<1-10	-	-	3-130
Cond	umhos/cm	<1-800	-	-	120-300	-	-	200-800
DO	mg/l	0.5-14	1-8	0.3-7.5	2-10	-	-	0-20
NH_3+NH_4^+	mg/l	<0.05-0.2	-	-	0.09-0.24	-	-	0.1-2.5
NO_2^-+NO_3^-	mg/l	0.05-0.06	-	-	0.07-0.16	-	-	0.1-2.2
PO_4^{3-}	mg/l	0.05-0.08	-	-	0.1-0.23	-	-	0.1-0.75
pH	mg/l	6.9-10.4	7.0-8.0	7.5-8.5	7.5-9.0	7.3-9.0	7.0-9.8	6.8-9.5
TSS	mg/l	2-30	1-35	10-80	1-13	3-48	1-80	8-80

Values adapted from: ODEQ (1995) *Water Quality Model of the Klamath River between Link River and Keno Dam (DRAFT)*. Prepared by CH2M HILL and S. Wells. December; and USBR WQ monitoring 2000.

Table 2-3
Lake Ewauna/Keno Reservoir Water Quality

Parameter	Units	KSD	Miller Island	Keno Bridge
BOD_u	mg/l	10	<3-10	<3-8
CHl_a	ug/l	3-130	-	40-60
Cond	umhos/cm	200-800	100-200	130-315
DO	mg/l	0-20.0	0.3-11.0	0.5-9.0
NH_3+NH_4^+	mg/l	0.1-2.5	0.1-1.5	0.1-1.5
NO_2^-+NO_3^-	mg/l	0.1-2.2	<0.05-2.3	<0.05-1.9
PO_4^{3-}	mg/l	0.1-0.75	<0.05-0.5	<0.05-0.6
pH	mg/l	6.8-9.5	7.0-9.3	7.0-9.0
TSS	mg/l	8-80	-	-

Miller Is. And Keno Bridge from 2000-2001 data. KSD from Table 2.

- This data and previous modeling as reported in ODEQ (1995) indicates that internal processes (e.g., SOD, primary production, nutrient cycling) play a large role in the water quality response of LEKR. Work completed by ODEQ (1995) suggests that 90 percent of the loading of BOD, ammonia, and phosphate comes from Link River inflows, internal processes (e.g., SOD), or groundwater inflow. Nitrate is the exception, where Link River and groundwater contribute just over 30% of the total inputs. In this case, KSD contributes about 25-30% of the nitrate, local WWTP contribute an additional 25-30%, and industrial uses 10-12%.

- Examining conditions within LEKR illustrate that water quality conditions improve in the downstream directions, probably due to time and distance from the bulk of the M&I discharges as well as Upper Klamath Lake. During portions of the year KSD discharges are of overall poorer quality than the lake (prior to about June 1), but during most of the summer KSD discharges are of equal or better water quality than the lake.

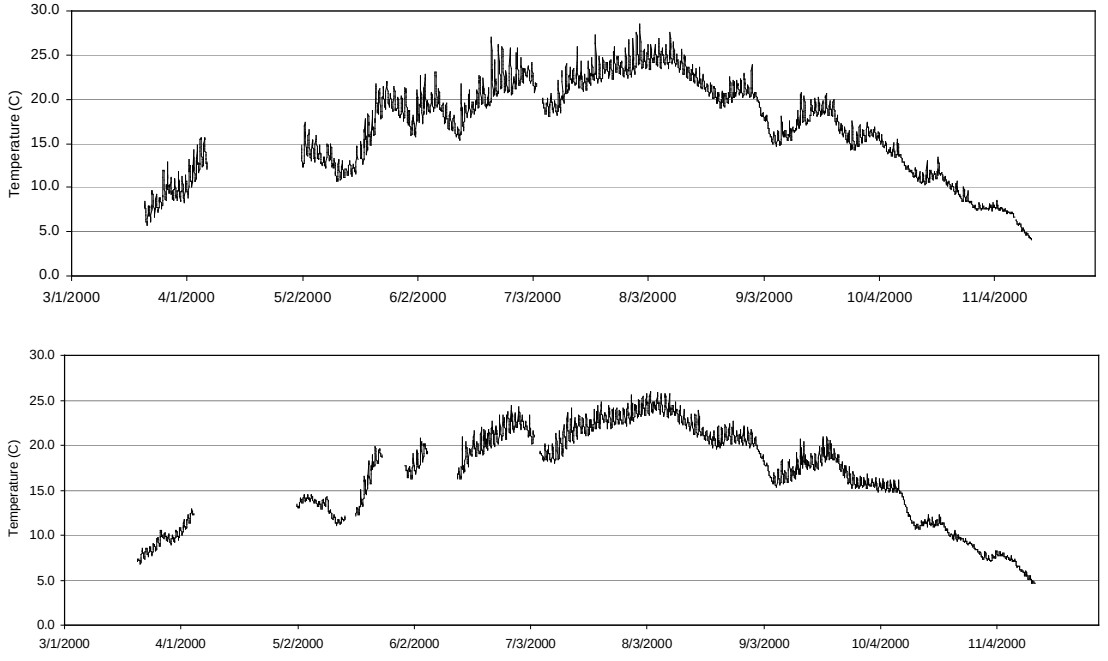


Figure 2-3
Water Temperatures Measured From Datasonde Deployment During 2000 In The Klamath River At Miller Island (RM 245) (Top Graph) And Klamath River At Keno (RM 233.3) (Bottom Graph)

- Water temperatures in LEKR show short-term meteorological variability (diurnal as well as cool and warm periods – days to weeks) imposed on a seasonal warming and cooling trend (Figure 2-3). The diurnal amplitude appears greater at the Miller Island site (RM 245) that at Keno (RM 233.3).

- Dissolved oxygen measurements fluctuate greatly in LEKR (Figure 2-4). Diurnal variations on the order of 10 mg/l per day during the late spring and early summer. Dissolved oxygen was near zero at the Miller Island site (RM 245) by about late June. Thereafter the system stays depressed for several weeks.

- These dissolved oxygen dynamics are probably caused by a combination of algal respiration, sediment oxygen demand, and UKL water quality and possibly other inputs. The system recovers around September 1, possibly because of a UKL water quality change, shortening day length, decreasing water temperature.

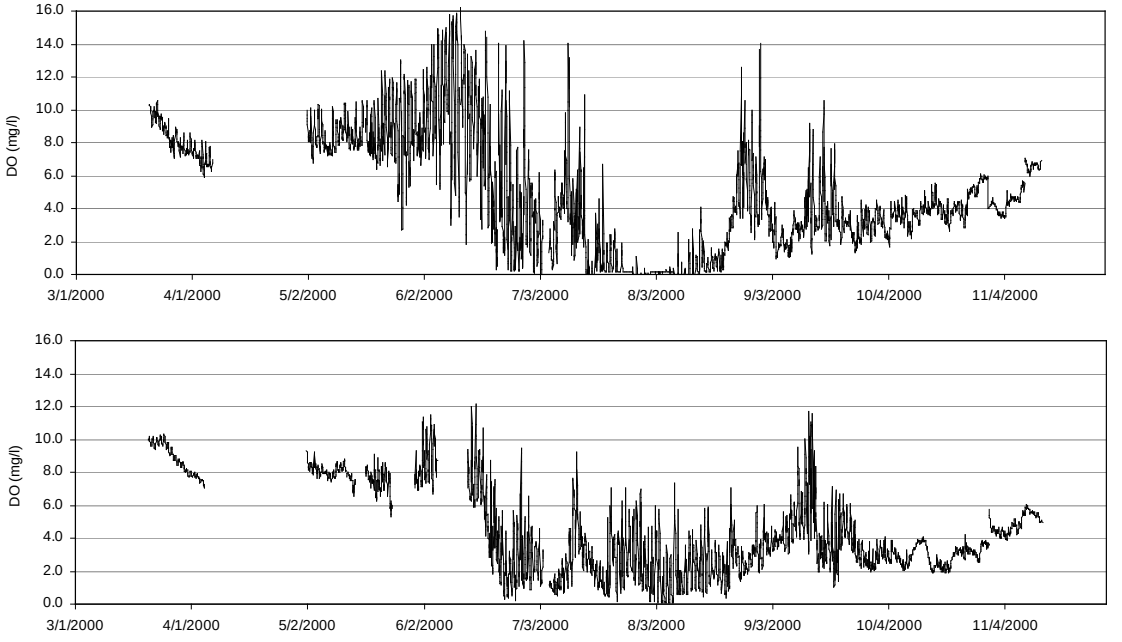


Figure 2-4
Dissolved Oxygen Measured From Datasonde Deployment During 2000 In The Klamath River At Miller Island (RM 245) (Top Graph) And Klamath River At Keno (RM 233.3) (Bottom Graph)

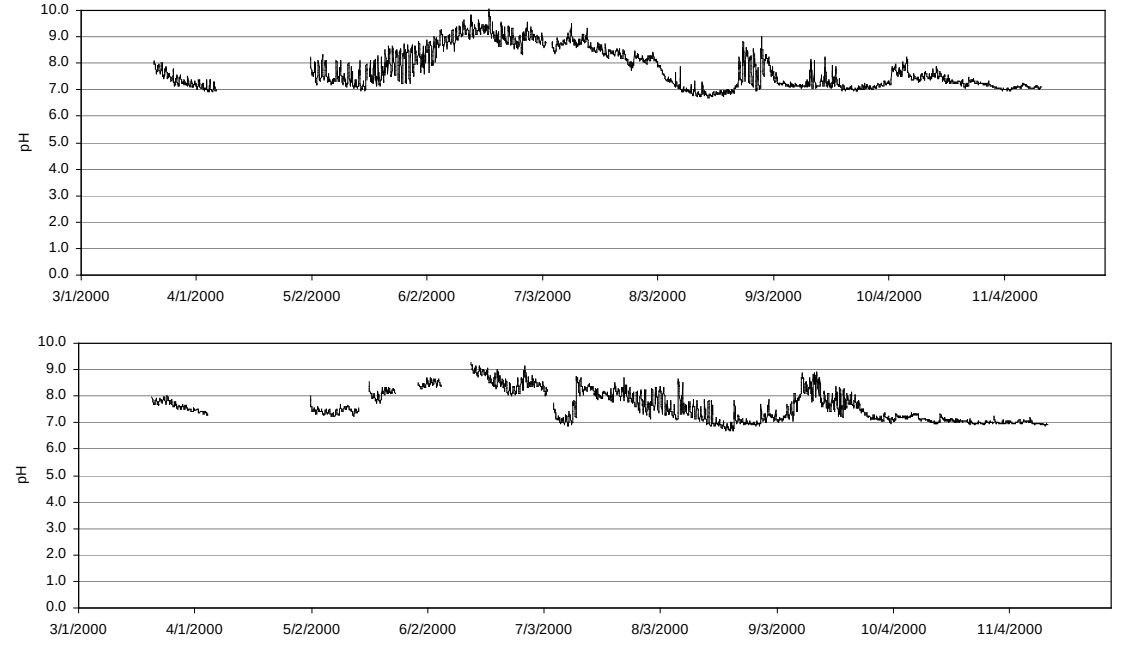


Figure 2-5
pH Values Measured From Datasonde Deployment During 2000 In The Klamath River At Miller Island (RM 245) (Top Graph) And Klamath River At Keno (RM 233.3) (Bottom Graph)

- Values of pH in these moderately buffered waters exceed 7 most of the time and temporarily exceed 9 during late June, probably as a result of high primary production..

- The portion of the Klamath River that includes the LEKR is 303(d)-listed for pH (summer), water temperature (summer), chlorophyll a (summer), dissolved oxygen (April 1-November 30), and toxics (ammonia; summer and winter). Nuisance phytoplankton and high pH, along with high nutrient concentrations, indicate that algal photosynthesis and respiration processes are key factors affecting water quality conditions in LEKR.

303(d) Listed Water Quality Parameters

- pH (summer)
- Water temperature (summer)
- Chlorophyll a (summer)
- Dissolved oxygen (April 1-November 30)
- Toxics (ammonia; summer and winter)

- Box plots of total phosphorus and nitrate nitrogen (Figures 2-6 and 2-7) were produced from data at selected sites sampled in LEKR from 1972 –2001 as listed in the following table. Two sites represented are not in the Klamath River, but represent portions of the irrigation system that may influence water quality in the Klamath River.

Site	Site ID	Number of Samples	Range of Dates
Klamath River at Hwy 66 (Keno)	23420	206	5/16/72 -- 3/13/01
Klamath River U/S of Klamath Strait	24200	36	4/17/90 -- 3/1/00
Klamath River at Miller Island boat Ramp	24570	43	4/17/90 -- 3/23/98
Klamath River @ Hwy 97 Bridge	24940	124	5/16/72 -- 6/20/01
Klamath Strait at USBR Pump Station F	KSD001	227	5/16/72 -- 6/20/01
Lost River Diversion Canal at Klamath River	LRD001	27	4/1/90 -- 3/23/98

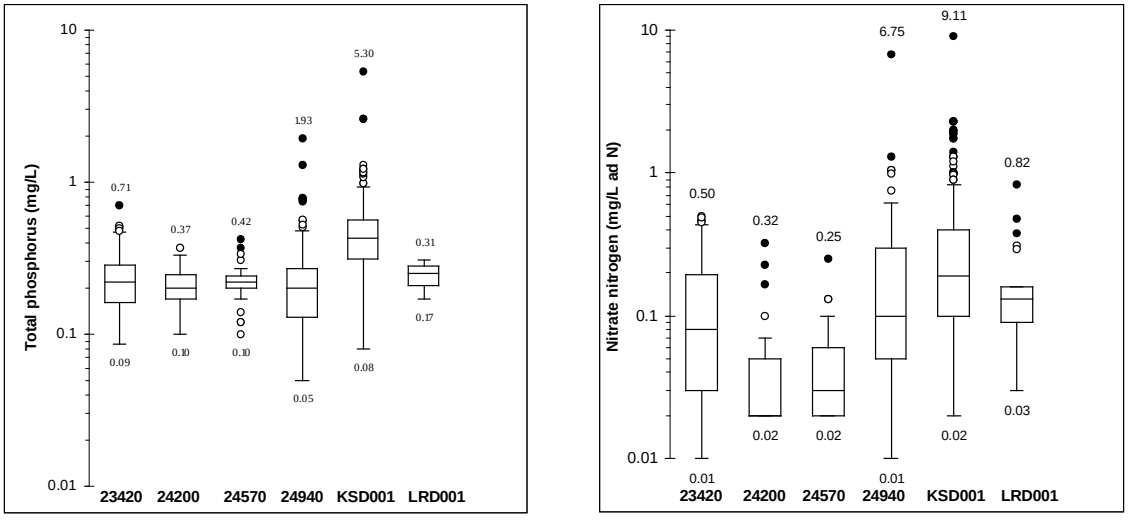


Figure 2-6
Box Plot Of Total Phosphorus (Left) and Nitrate Nitrogen (Right) Measured In Water Samples Collected From Selected Sites In Lake Ewauna And Keno Reservoir 1972 -2001.

- Box plots (Figure 2-6) indicate that total phosphorus concentration is highly variable (note logarithmic scale) and is higher in Klamath Straits Drain than at the other sites sampled. Nitrate nitrogen exhibits a wide range of concentration (note the logarithmic scale). Sites 24200 (upstream of Klamath Straits drain) and 24570 (Miller Island boat ramp) may have slightly lower nitrate concentration than other sites in this reach.

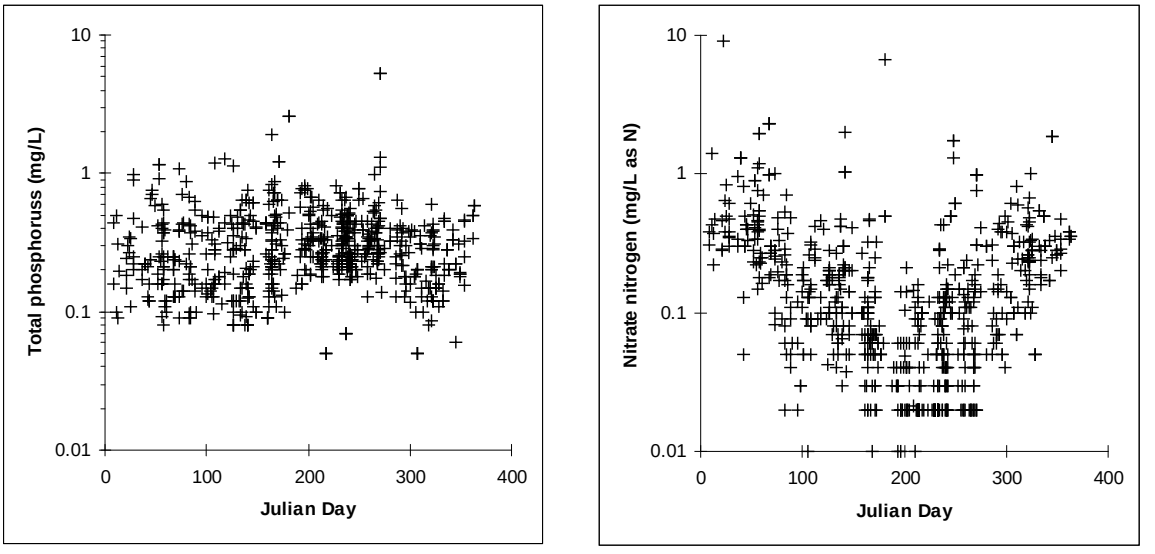


Figure 2-7
Scatter Plots Showing Total Phosphorus (Left) And Nitrate Nitrogen (Right) Concentrations Measured In All Samples From Selected Sites Distributed Throughout The Calendar Year

- Scatter plots (Figure 2-7) show the variability of phosphorus and nitrate nitrogen concentrations throughout the calendar year in the selected sites measured in LEKR. Unlike nitrate nitrogen, there does not appear to be an obvious seasonal pattern in total phosphorus concentration. A seasonal pattern of nitrate concentration is evident with lower values in the summer and higher values in the winter.

Available Data and Information

- **Previous WQ Monitoring (1972 to 2001)**. The following table lists sites sampled by various sources in the LEKR reach of the Klamath River between RM 233 and RM 253 from 1972 to 2001.

Reach	Site Name	Sample Count	Min Date	Max Date	Source
2	ADY Canal Headworks	3	06/18/74	08/27/74	BOR
2	ADYInlet -A	18	03/17/98	11/17/98	USGS
2	Keno -A	35	04/25/96	11/17/98	USGS
2	Klamath River at Miller Island boat Ramp	24	04/17/90	03/23/98	DEQ
2	Klamath River Hwy 97 Bridge	65	05/16/72	08/25/93	DEQ
2	Klamath River Keno Bridge	40	05/16/72	07/11/78	DEQ
2	Klamath River @ Hwy 97 Bridge (K-10, 52697)	36	05/21/91	06/20/01	BOR
2	Klamath River 100' D/S S Suburban STP Discharge	1	08/07/90	08/07/90	DEQ
2	Klamath River 100' U/S Klamath Falls STP	1	07/12/88	07/12/88	DEQ
2	Klamath River 1000' D/S Klamath Strait	1	08/08/90	08/08/90	DEQ
2	Klamath River 1000' U/S Klamath Strait	1	08/08/90	08/08/90	DEQ
2	Klamath River 120' D/S Klamath Falls STP	1	08/07/90	08/07/90	DEQ
2	Klamath River 150' D/S Klamath Strait	1	08/08/90	08/08/90	DEQ
2	Klamath River 150' U/S Klamath Falls STP	1	07/12/88	07/12/88	DEQ
2	Klamath River 1500' U/S Klamath Strait	2	08/08/90	02/29/00	DEQ
2	Klamath River 20' D/S S Suburban STP Discharge	1	08/07/90	08/07/90	DEQ
2	Klamath River 20' U/S Klamath Strait	1	08/08/90	08/08/90	DEQ
2	Klamath River 200' D/S S Suburban STP Discharge	1	08/07/90	08/07/90	DEQ
2	Klamath River 30' D/S S Suburban STP Discharge	1	08/07/90	08/07/90	DEQ
2	Klamath River 300' D/S S Suburban STP Discharge	1	08/07/90	08/07/90	DEQ
2	Klamath River 50' U/S Klamath Falls STP	1	08/07/90	08/07/90	DEQ
2	Klamath River at East Side of Gorr Island	16	04/17/90	03/02/00	KRIS
2	Klamath River at Hwy 66 (Keno)	117	01/21/80	03/13/01	KRIS
2	Klamath River at Hwy 97 Br NE	11	04/17/90	03/23/98	DEQ
2	Klamath River at Hwy 97 Br SE	11	04/17/90	08/16/94	DEQ
2	KLAMATH RIVER AT HWY 97 BRIDGE	25	04/28/87	08/25/93	STORET/KRIS
2	Klamath River at Irrigation Pumphouse	14	06/13/90	03/02/00	STORET
2	KLAMATH RIVER AT KENO BRIDGE	1	04/28/87	04/28/87	KRIS
2	Klamath River at KLAD Radio Tower	10	04/17/90	08/16/94	DEQ
2	Klamath River at Powerline Crossing (D/S Strait	16	04/17/90	03/02/00	DEQ
2	Klamath River at River Mile 242	3	06/13/90	08/17/94	DEQ
2	Klamath River at South End of Dog Pound Island	10	06/12/90	08/16/94	DEQ/KRIS
2	Klamath River at South-side Bypass Bridge	16	06/13/90	03/23/98	KRIS
2	Klamath River at Weyerhaeuser Mill Smokestack	7	08/28/90	08/16/94	KRIS
2	Klamath River D/S Gorr Is @ Teeters Landing	2	02/29/00	03/02/00	DEQ
2	Klamath River D/S of North Canal (Midland)	14	06/13/90	03/01/00	DEQ/KRIS
2	Klamath River Directly South of Hill 4315	8	08/28/90	02/29/00	DEQ
2	Klamath River U/S of Klamath Strait	14	04/17/90	03/01/00	DEQ
2	Klamath Strait 200' D/S Pump Station F (S Chan)	2	08/08/90	08/08/90	DEQ
2	KLAMATH STRAIT AT HWY. 161	2	03/28/95	03/29/95	STORET
2	Klamath Strait at USBR Pump Station F	109	01/21/80	03/13/01	DEQ
2	Klamath Straits Drain (KSD) Stateline	136	05/16/72	11/23/93	KRIS
2	Klamath Straits Drain (KSD) @ Stateline (K-2, 52691)	37	05/21/91	02/27/01	BOR

Reach	Site Name	Sample Count	Min Date	Max Date	Source
2	Lake Ewauna at Railroad Bridge Drawspan	13	08/07/90	03/23/98	DEQ
2	Lake Ewauna between STPs	13	06/12/90	08/16/94	DEQ
2	Lost River Diversion Canal at Klamath River	16	04/17/90	03/23/98	DEQ
2	Lost River Diversion Canal D/S of Dam (K Falls)	1	04/17/90	04/17/90	DEQ
2	North Ditch U/S South Suburban STP	1	10/16/90	10/16/90	DEQ
2	North Ditch U/S West Drainage Canal	1	08/08/90	08/08/90	DEQ
2	Pumping Plant F	108	05/16/72	06/20/01	USGS
2	Pumping Plant F (K-1, 52690)	39	05/20/91	06/20/01	BOR
2	South Ditch U/S South Suburban STP Discharge	1	09/25/90	09/25/90	DEQ
2	West Ditch 15' U/S of Mouth (D/S STP Outfall)	1	08/07/90	08/07/90	DEQ
2	West Ditch U/S of North Canal	1	08/08/90	08/08/90	DEQ

- **Recent WQ Monitoring (1998 to Present)**. In 1998 the USBS-Biological Resources Division (USGS-BRD) implemented a basin-wide monitoring program with support from USBR. Data were collected from Klamath Falls to below the Trinity River, as well as in the Klamath Reclamation Project and selected tributaries. This program was repeated in 1999. Throughout this period PacifiCorp monitored physical parameters in main stem reservoirs. During 2000 the program was revamped by USBR and PacifiCorp expanded their monthly physical profile monitoring to include deployment of temperature thermistors as well as grab sampling for nutrients and BOD. During the 2001 field season, USBR and PacifiCorp with support from USFWS were able to maintain all sampling locations monitored in 2000. This program, implemented by USGS-BRD in 1998, has become the most extensive, continuous, and valuable water quality effort in the basin. The program includes grab sample data at semi-monthly intervals from May through November, as well as continuous deployment of DataSonde water quality probes at over a dozen locations. Sites within LEKR include the Klamath River at Miller Island (RM 246).