3. Streamflow timing investigation

3.1 High flow intervals

The high flow intervals for three drainage areas of Pasak watershed studied under this investigation (S4B, S13 and S9) in terms of quarter flow and half flow as derived from cumulative hydrograph for each drainage area (shown in Appendix F) were given in Table 32, 33 and 34. The mean annual quarter flow intervals were found 28, 17 and 17 days and half flow intervals were found 72, 54 and 47 days for S4B (upper Pasak), S13 (middle part of Pasak) and S9 (lower Pasak) respectively. On average, quarter flow intervals were 11 days more shorter in S4B of upper Pasak than in S13 and S9 and half flow intervals were 18 days and 25 days more shorter in S4B than in S13 and S9 respectively. This may be because flow in S4B is discharged over a longer period of time and timing show less variation.

Table 32 Streamflow timing parameters indicated by flow dates and flow intervals in water-year basis (1969-2001) for Pasak watershed at Mueang, Muang Phechabun (S4B)

	Flow Intervals (Days)				Flow dates		
	High - flow		Low - flow				
Year	Quarter flow	Half flow	5 % flow	1% flow	1st quartile	Half flow	3rd quartile
1969	39	89	77	69	Aug 11 (133)	Sep 19 (172)	Nov 08 (222)
1970	30	79	35	7	Aug 13 (135)	Sep 12 (165)	Oct 31 (214)
1972	42	91	52	5	Aug 17 (139)	Oct 05 (188)	Nov 16 (230)
1973	71	163	26	6	July 27 (118)	Oct 06 (189)	Jan 06 (281)
1974	55	139	88	8	June 26 (87)	Sep 18 (171)	Nov 12 (226)
1978	21	65	51	17	Aug 04 (126)	Sep 17 (170)	Oct 08 (191)
1979	51	104	92	19	June 24 (85)	Aug 16 (138)	Oct 06 (189)
1980	23	66	70	39	July 30 (121)	Sep 11 (164)	Oct 04 (187)
1981	20	77	85	14	July 26 (117)	Aug 15 (137)	Oct 11 (194)
1982	19	50	45	13	Sep 10 (163)	Sep 29 (182)	Oct 30 (213)
1983*	24	64	69	12	Aug 29 (151)	Sep 22 (175)	Nov 01 (215)
1995	15	34	153	106	Aug 17 (139)	Sep 05 (119)	Sep 20 (173)
1996	17	38	131	97	Sep 03 (156)	Sep 24 (177)	Oct 11 (194)
1997	15	40	151	113	Aug 30 (153)	Sep 14 (168)	Oct 09 (193)
1998	17	55	162	120	July 17 (108)	Aug 24 (146)	Sep 10 (163)
1999	16	33	135	95	Aug 28 (150)	Sep 14 (167)	Sep 30 (183)
2000	22	72	153	107	July 07 (98)	Aug 26 (148)	Sep 17(170)
2001	12	45	137	112	Aug 09 (131)	Aug 21 (143)	Sep 23 (176)
Mean	28	72	95	53	128 (Aug 06)	162 (Sep 09)	201 (Oct 18)

Table 33 Streamflow timing parameters indicated by flow dates and flow intervals in water year basis (1979 - 2002) for middle part of Pasak watershed at Ban Tha Yiam, Chai Badan, Lopburi (S13)

	Flow interval (Days)				Flow Dates					
	High - flow		Low-flow							
Year	Quarter flow	Half flow	5 % flow	1% flow	1st quartile flow date		Half flow date		3rd quartile date	flow
1979	3	49	102	55	Aug-10	132	Aug-13	135	Sep-28	181
1980	17	37	145	102	Aug-31	153	Sep-20	173	Oct-07	190
1981	22	79	76	22	Jul-21	112	Aug-12	134	Oct-08	191
1982	2	21	143	70	Sep-09	162	Sep-11	164	Sep-30	183
1983	5	27	98	42	Sep-19	172	Oct-11	194	Oct-16	199
1984	24	85	154	90	Jul-13	104	Sep-12	165	Oct-06	189
1985	9	45	66	50	Aug-11	133	Sep-16	169	Sep-25	178
1986	13	31	38	29	Aug-10	132	Aug-28	150	Sep-10	163
1987	11	26	120	63	Sep-08	161	Sep-19	172	Oct-04	187
1988	58	138	67	15	Jun-02	63	Aug-21	143	Oct-18	201
1989	24	73	110	60	Aug-02	124	Aug-26	148	Oct-14	197
1990	6	27	103	27	Sep-12	165	Sep 18	171	Oct-09	192
1991	9	32	156	84	Aug-28	150	Sep-20	173	Sep-29	182
1992	7	53	82	29	Aug-06	128	Aug-13	135	Sep-28	183
1993	30	61	70	47	Jul-29	120	Aug-29	151	Sep-28	181
1994	24	65	152	51	Jul-16	107	Aug-26	148	Sep-29	172
1995	16	38	161	57	Aug-10	132	Aug-26	148	Sep-17	170
1996	27	72	103	39	Jul-27	118	Sep-10	163	Oct-07	190
1997	22	68	121	46	Aug-07	129	Sep-22	175	Oct-14	197
1998	27	62	151	103	Aug-11	133	Sep-15	168	Oct-12	195
1999	27	91	144	109	Jul-12	103	Sep-14	167	Oct-11	194
2000	15	43	45	59	Jul-28	119	Aug-25	147	Sep-09	162
2001	3	48	69	43	Aug-08	130	Aug-11	133	Sep-25	178
2002	8	22	126	28	Sep-01	154	Sep-09	162	Sep-23	176
Mean	17	54	108	55	Aug-09	131	Sep-05	158	Oct-02	185

Table 34 Streamflow timing parameters indicated by flow dates and flow intervals in water-year basis (1974-2002) at Ban Pa, Kaeng Khoi, Saraburi (S9)

	Flow Intervals (Days)						
	High - flow		Low flow		Flow dates		
Year	Quarter flow	Half flow	5 % flow	1% flow	1st quartile date	Half flow date	3rd quartile date
1974	19	38	107	27	Sept. 25(178)	Oct.14(197)	Nov. 2 (216)
1975	16	32	133	61	Sept.14(167)	Sept. 30(183)	Oct.16(199)
1976	19	43	120	51	Sept. 12(165)	Oct. 06 (189)	Oct. 25(208)
1977	8	18	134	49	Sept.17(170)	Sept.27(180)	Oct. 05(188)
1978	6	38	151	63	Aug.30(152)	Oct.02(185)	Oct.08(191)
1979	15	81	128	42	July 17(108)	Sept.21(174)	Oct. 06(189)
1980	11	35	133	53	Sept. 9(162)	Oct.03(186)	Oct. 14(197)
1981	23	54	120	55	Aug 14(136)	Sept.06(159)	Oct.07(190)
1982	14	28	117	47	Sept. 19(172)	Oct. 3(186)	Oct.17 (200)
1983	13	31	135	52	Sept.27(180)	Oct.15(198)	Oct. 28(211)
1984	18	39	108	30	Sept.14(167)	Oct. 5(188)	Oct.23(206)
1985	22	48	115	43	Sept.8(161	Sept.30(183)	Oct.26(209)
1986	24	54	87	21	Aug 9(131)	Sept. 8(161)	Oct. 2(185)
1987	10	25	153	65	Sept. 20(172)	Sept.30(182)	Oct. 15(197)
1988	36	126	113	49	June 26(87)	Sept.24(177)	Oct. 30(213)
1989	33	96	123	60	July 17(108)	Sept.18(171)	Oct. 21(204)
1990	16	68	131	82	Aug 15(137)	Oct.6(189)	Oct. 22(205)
1991	16	34	146	61	Sept.4(157)	Sept. 20(173)	Oct. 8(191)
1992	16	50	119	50	Aug 26(148)	Sept. 29(182)	Oct 15(198)
1993	10	25	100	23	Sept. 9(162)	Sept.24(177)	Oct. 4(187)
1994	14	39	159	93	Aug 24(146)	Sept. 18(171)	Oct. 2(185)
1995	11	33	151	100	Aug 29(151)	Sept. 20(173)	Oct. 1(184)
1996	13	35	126	76	Sept.17(170)	Oct. 9(192)	Oct.22(205)
1997	16	39	126	61	Sept.13 (166)	Oct. 6(189)	Oct 22(205)
1998	27	56	142	36	Aug. 24 (146)	Sept.22 (175)	Oct. 19(202)
Mean*	17.04	46.6	127.08	54	Aug 30 (152)	181(Sep 28)	Oct 16 (199)
1999	20	40	60	29	Sept. 25(178)	Oct. 15 (198)	Nov. 4 (218)
2000	21	68	88	33	July 26 (117)	Set. 11 (164)	Oct. 2 (185)
2001	53	118	30	12	July 2 (93)	Aug 24 (146)	Oct 28 (211)
2002	9	19	71	17	Sept. 15(168)	Sept.24 (177)	Oct 4 (187)
Mean**	25.75	61.25	62.25	22.75	Aug 17 (139)	Sep 26 (179)	Oct 17 (200)

Note: * - Before dam construction, ** - after dam construction

3.2 Low flow intervals

The low flow intervals for three drainage areas - S4B, S13 and S9 of Pasak watershed in terms of 5% flow and 1% flow as derived from cumulative hydrograph for each drainage areas (shown in Appendix F) were given in Table 32,

33 and 34. The mean annual 5% flow intervals were found 95, 108 and 127 days and 1% flow intervals were found 53, 55 and 54 days for S4B (upper Pasak), S13 (Middle part of Pasak Pasak) and S9 (Lower Pasak) respectively. On average, 5% flow intervals were 13 and 32 days less longer in S4B of upper pasak than in S13 and S9 respectively and 1% flow intervals were 2 days and 1 days less longer in S4B than in S13 and S9 respectively. Thus the S4b drainage area in upper Pasak that have the shortest low flow interval have shortest dispersion and shortest flow variability than other two drainage areas in lower Pasak indicating somewhat better condition of forest resources in upper part of Pasak watershed. This part has more water storage than the other two and that is why it can generate dry flow in a less longer time.

3.3 Flow dates

The mean annual flow dates in terms of 1st quartile flow, half flow and 3rd quartile flow for the three studied drainage areas (upper Pasak at S4B), middle Pasak at S13 and lower Pasak at S9) as shown in the same table 32, 33 and 34 were found 128th (Aug-06), 131st (Aug-09) and 152nd (Aug-30) in terms of 1st quartile flow date; 162nd (Sep-09), 158th (Sep-05) and 181st (Sep-28) day in terms of half flow date; and 201st (Oct-28), 185th (Oct-02) and 199th (Oct-16) day in terms of 3rd quartile flow date for S4B, S13 and S9 respectively.

3.4 Flow timing pattern

3.4.1 Flow interval trend

The streamflow timing pattern in terms of high and low flow intervals for upper, middle and lower Pasak using time series analysis with moving average of 5, 10 and 15 years were shown in Figure 27, 28 and 29.

For upper Pasak, trend of high flow interval including shortest quarter flow and half flow interval during the period 1969 – 2001 (Figure-27) showed decreasing trend which indicate shortest flow interval will become more shorter in the

near future. Large quantity of runoff will be increasingly occurred in a shorter period of time. This might be because of increasing rate of deforestation, nature of topography, etc. On the other hand, trend of low flow interval including 5% and 1% flow interval during the same period (Figure-27) show increasing trend that indicate longest flow interval will become more longer in the near future. Small quantity of runoff will be increasingly occurred in a longer period of time implying that less quantity of water would be served for utilization in the dry period in future. The reason behind this timing variation might be the same as mentioned above.

For the drainage area in middle part of Pasak, trend of high flow interval during the period 1976 – 2002 (Figure 28) showed increasing trend which seemingly indicate shortest flow interval becoming longer. The fact behind this situation might be the more influenced role of water withdrawal for agricultural purposes than deforestation. The low flow interval also showed the increasing trend due to the fact that small quantity of runoff occurred increasingly during dry period.

For lower Pasak, high flow interval trend during the period 1974 – 1998 i.e. before dam construction showed increasing trend indicating increasingly less water yield at the outlet S9 (Figure 29). It might be due to withdrawal of more water for agricultural purposes in the upland areas. The same trend was also found after dam construction as because more discharge was being trapped by the newly constructed reservoir. On the other hand trend of low flow interval including 5% and 1% flow interval during the whole period showed increasing trend due to small quantity of runoff occurred in a longer period of time indicating more water shortage in future during dry period.

3.4.2 Flow dates trend

The streamflow timing pattern in terms of 1st quartile, half flow and 3rd quartile flow date for upper, middle and lower part of Pasak at S4B, S13 and S9 gaging stations using moving average of 5, 10 and 15 years were shown in Figure 30, 31 and 32. For upper Pasak, the trend showed that the date at which 1/4th of discharge

occurred was increasingly moving backward of the water year whereas half flow date and 3rd quartile flow date were moving forward of the water year. It implies that 25% flow occurred in a longer time due to more evaporation and less antecedent moisture in the soil requiring longer period to saturate soil, whereas 50% and 75% flow occurring in a shorter time indicating more runoff in a short time resulting from less forest cover in the upstream areas. For middle part of Pasak, the date at which 25%, 50% and 75% of the total flow occurred were also moving forward of the water year indicating more runoff in a shorter period from a small drainage area. The same trend was also found for lower Pasak at S9 gaging station where 25% flow occurred distinctly at an earlier date in comparison to the past but the trends for half flow and 3rd quartile flow dates were found equal, not much increasing or decreasing. It was due to flat land of large areas and more water uses for agricultural purposes throughout the study period.

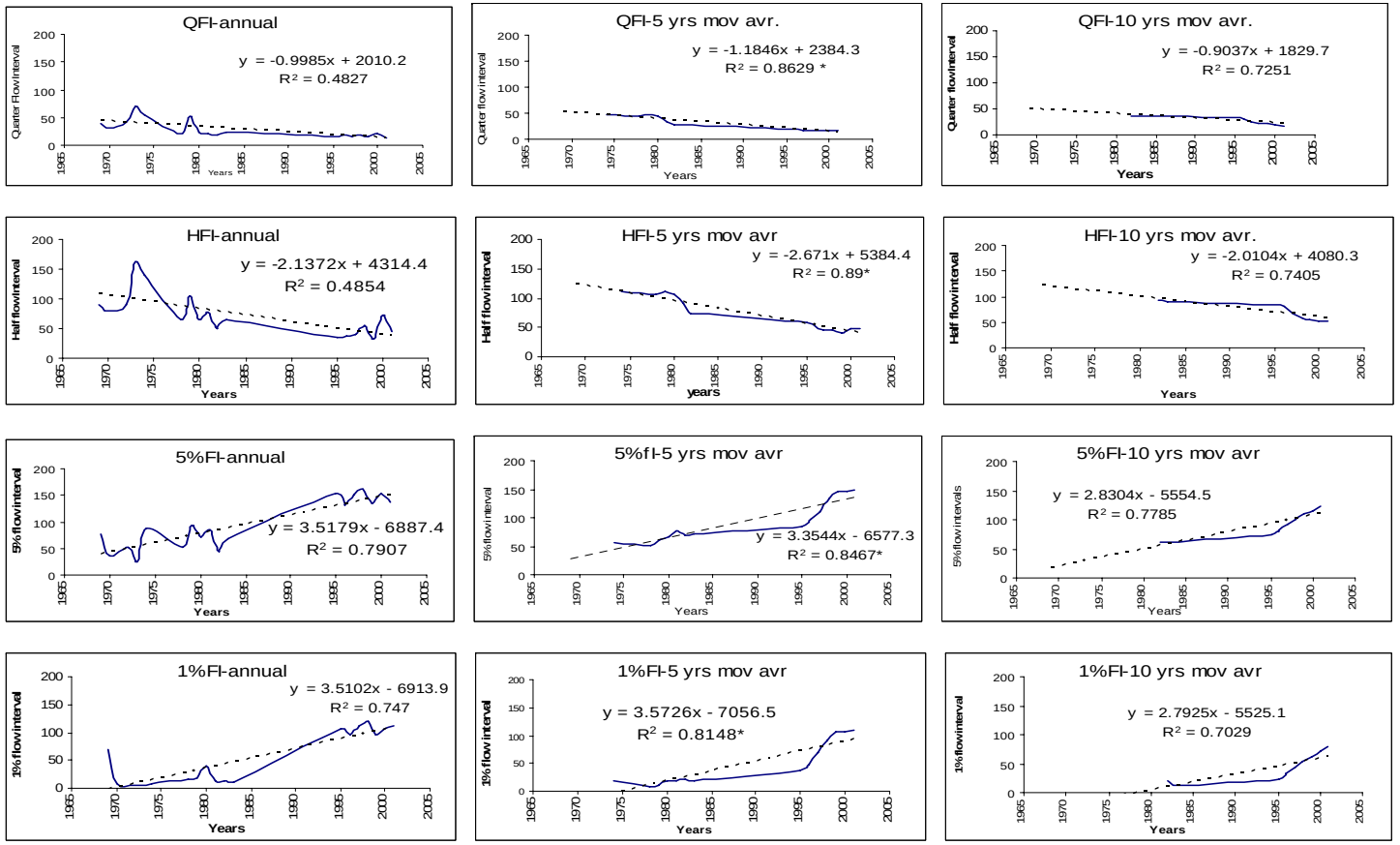

Figure 27 Streamflow timing pattern indicated by flow interval (1969-2001) of Upper Pasak Basin at Mueang, Muang Phechabun (S4B) using mov. avr. of 5 and 10 years.
Note: * indicate singnificant relationship at 99% confidence interval

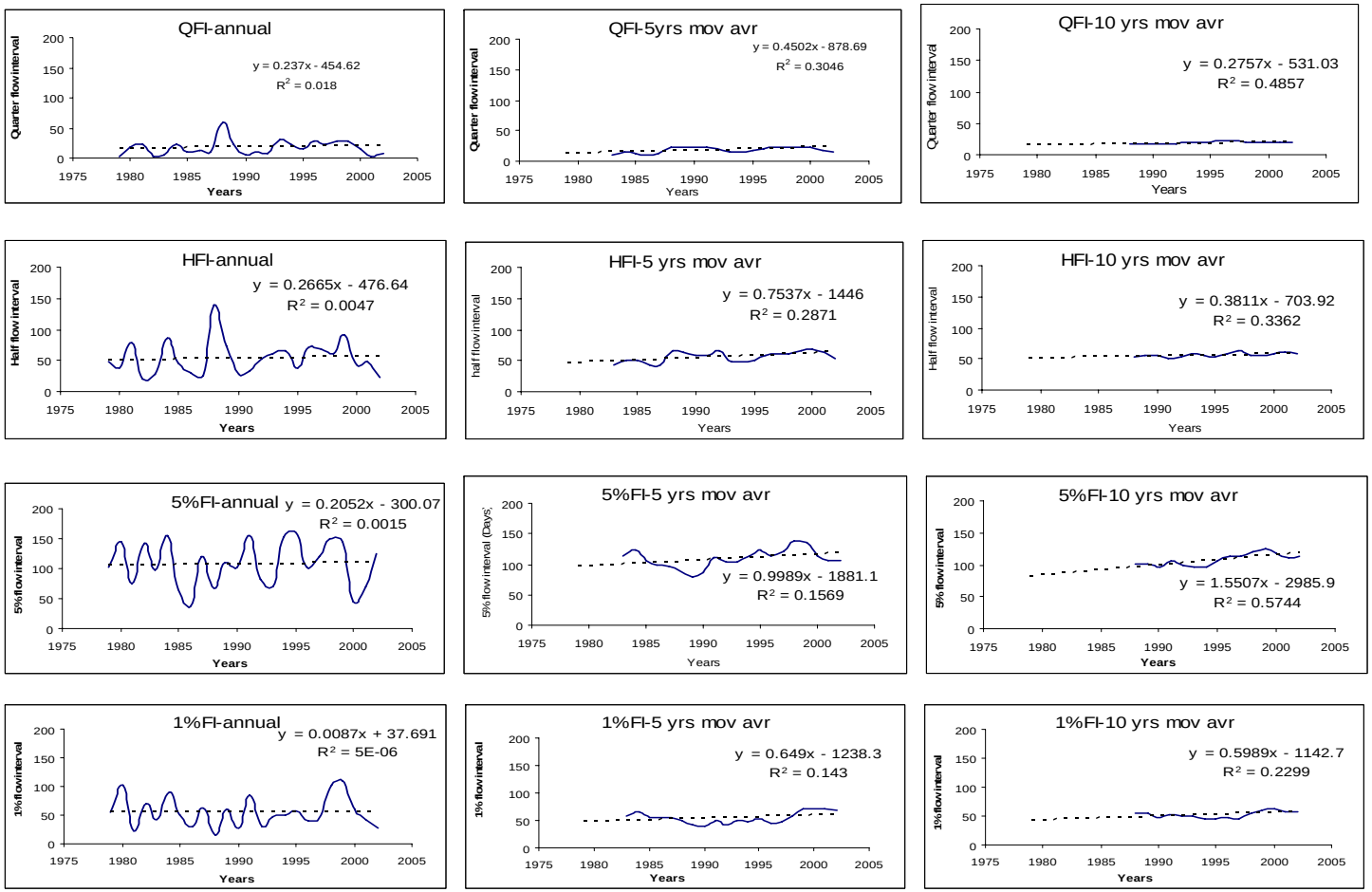

Figure 28 Streamflow timing pattern indicated by flow interval during period 1979-2002 of middle part of Pasak Pasak at Ban Tha Yiam, Chai badan, Lopburi (S13) using moving average of 5 and 10 yrs

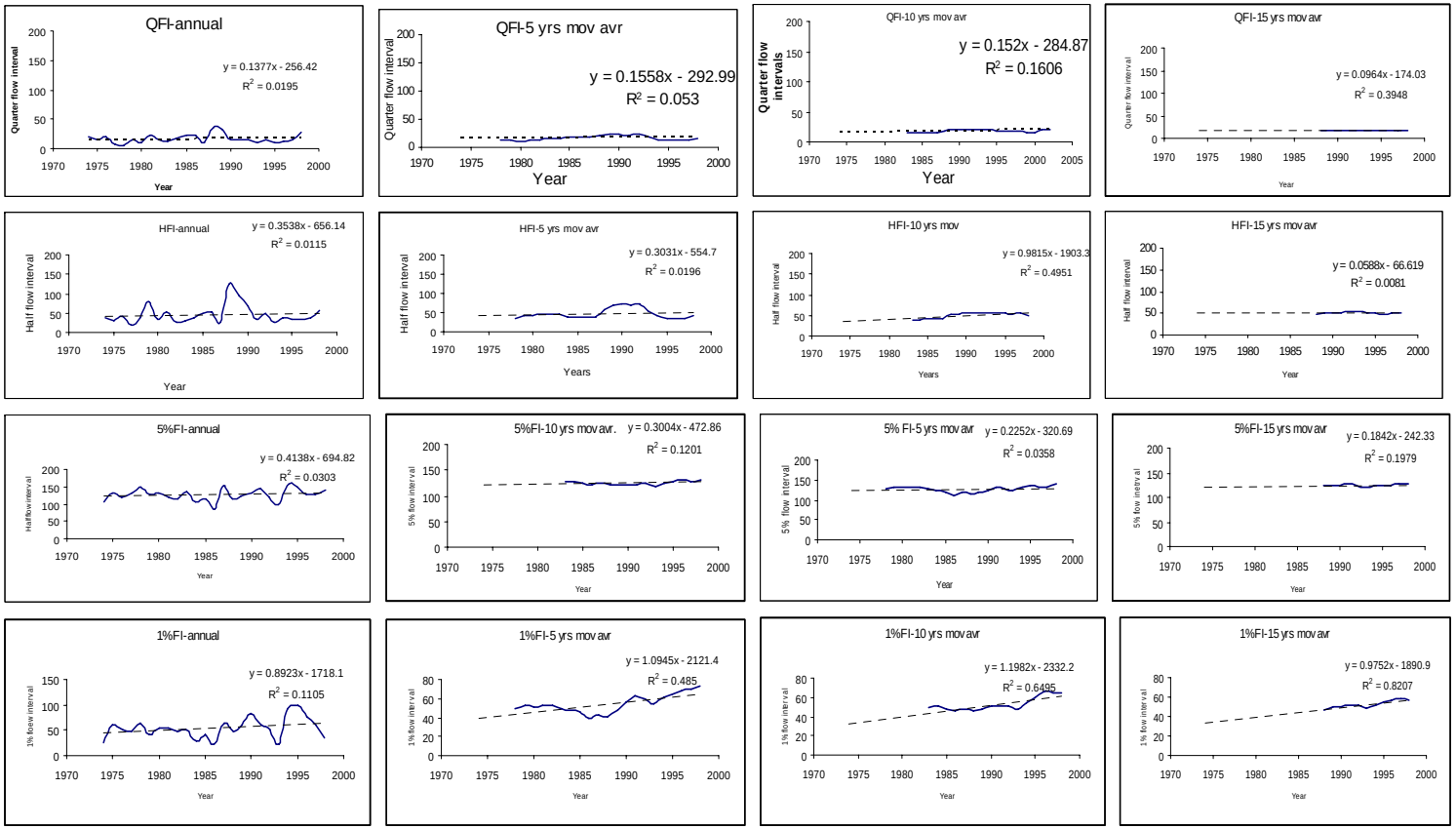

Figure 29 Flow timing pattern indicated by flow interval for the period 1974 - 2002 of lower Pasak at Ban Pa, Kaeng khoi, Saraburi (S9) using mov. Avr. of 5, 10 and 15 years

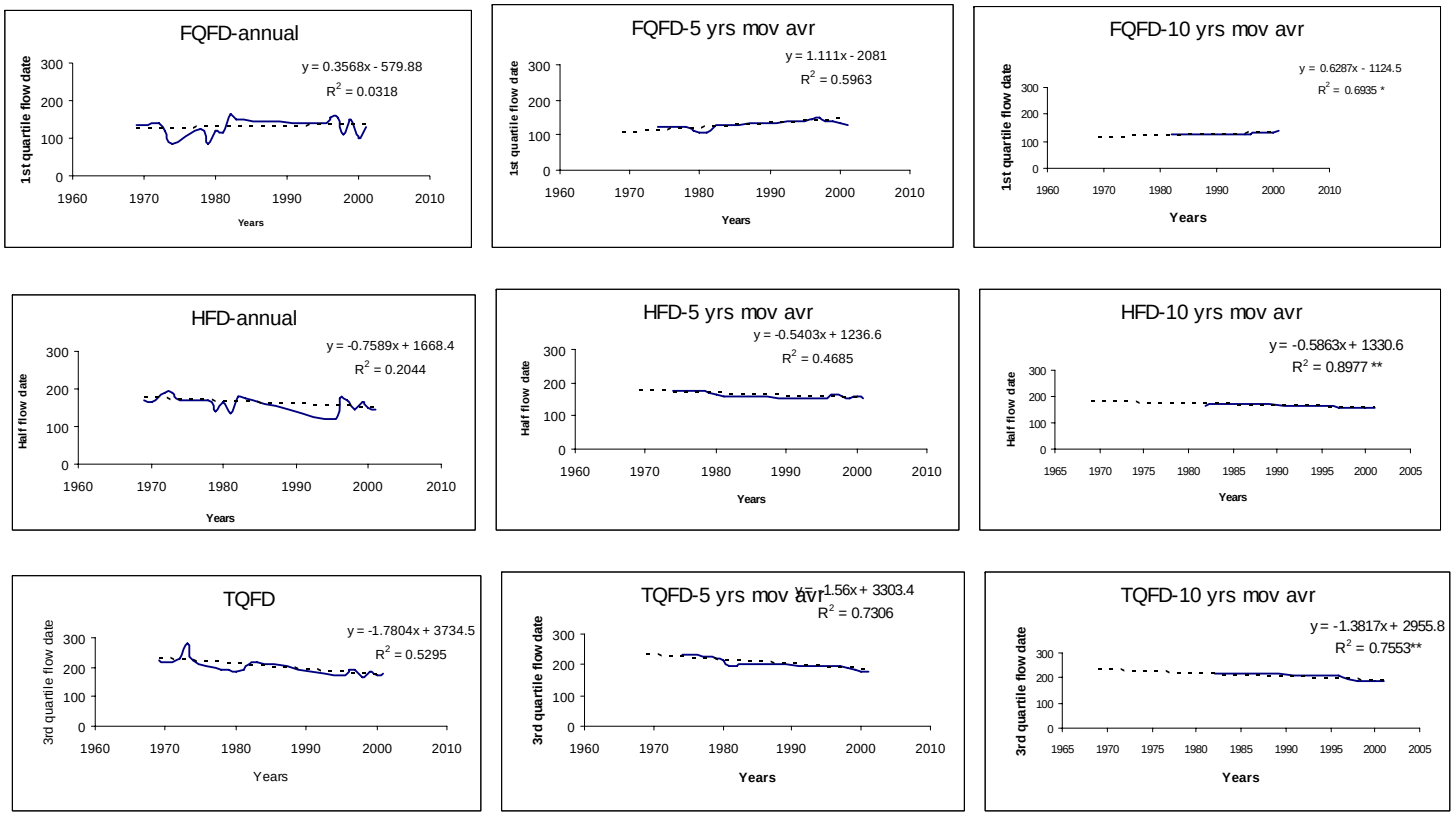

Figure 30 Flow timing pattern indicated by flow date for Upper Pasak at Mueang, Muang Phetchabun (S13) using moving average of 5 and 10 years

Note: FQFD – 1st quartile flow date, HFD – Half flow date, TQFD – 3rd quartile flow date:

* - significant at 95% confidence interval, ** - significant at 99% confidence interval

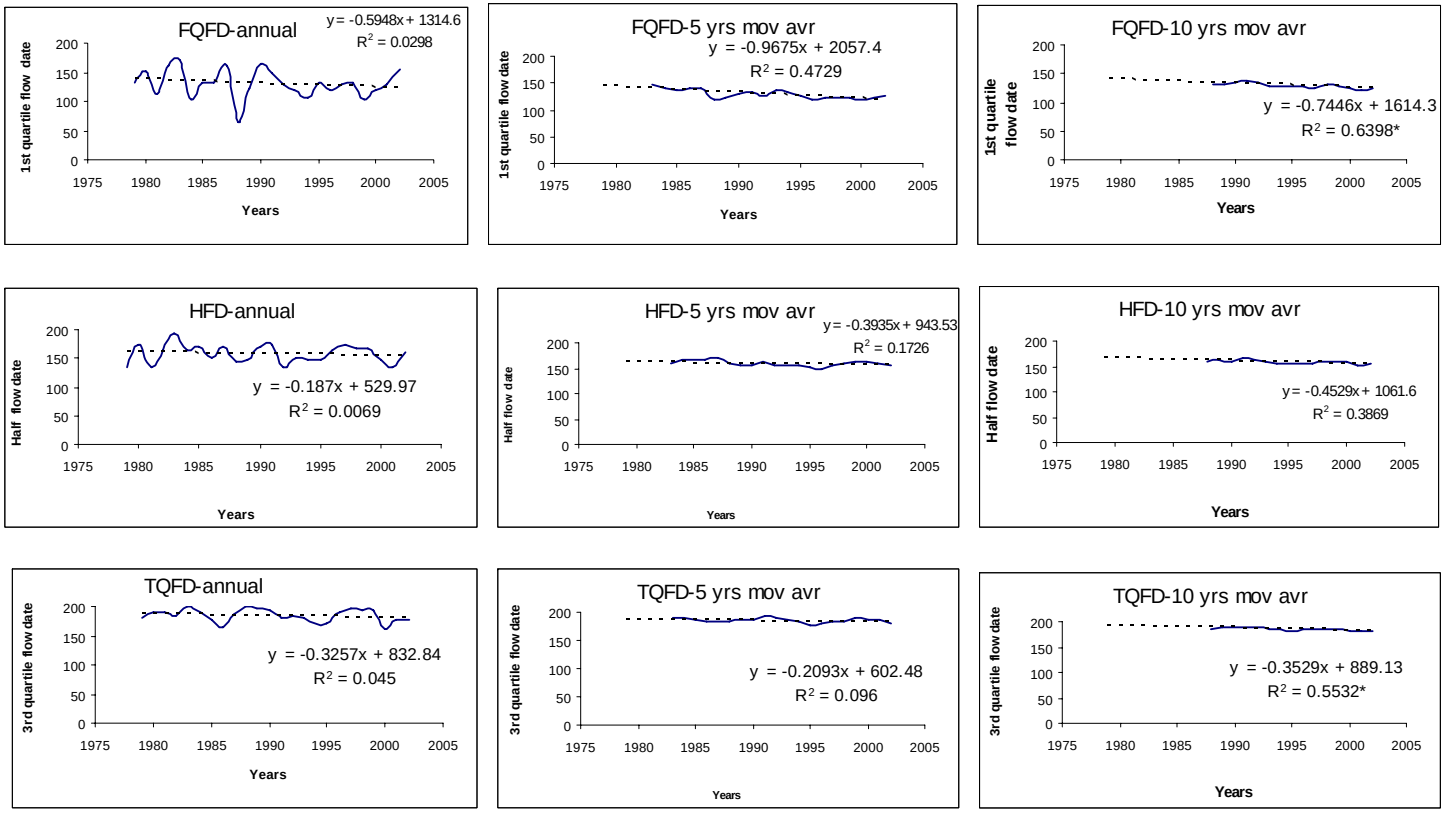

Figure 31 Flow timing pattern indicated by flow date for the period 1976-2002 for middle Pasak at Ban Tha Yiam, Chai Badan, lopburi (S13) using moving average of 5 and 10 years

Note: FQFD – 1st quartile flow date, HFD – Half flow date, TQFD – 3rd quartile flow date:
* sign indicate significant at 95% confidence interval.

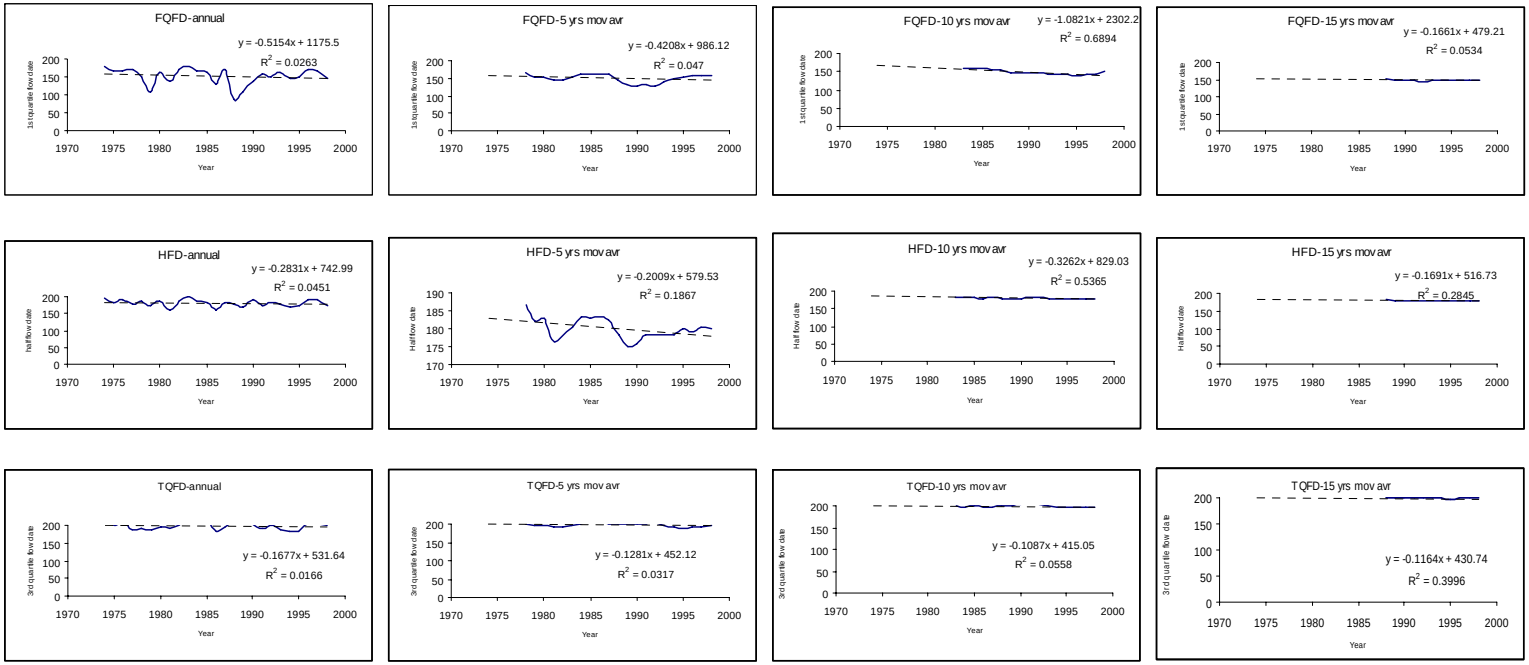

Figure 32 Flow timing pattern indicated by flow date for the period 1974 - 2002 of lower Pasak at Ban Pa, Kaeng khoi, Saraburi (S9) using mov. Avr. of 5, 10 and 15 years
Note: FQFD – 1st quartile flow date, HFD – Half floe date, TQFD – 3rd quartile flow date.