

# **WASKADA UNIT NO. 8**

## **WATERFLOOD PROGRESS REPORT**

**January 1, through December 31, 2011**

### **PennWest Exploration**

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Senior Waterflood Exploitation Engineer**

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## **INTRODUCTION**

The WASKADA UNIT NO.8 pressure maintenance project commenced water injection into the Lower Amaranth designed and in accordance with Manitoba Energy and Mines Approval No. PM 58.

**PRESSURE MAINTENANCE:** Governed by Board Order No. PM 58

### Unit Information:

**UNITIZED ZONE:** Lower Amaranth

Original Unit Sept.1, 1985 Board Order - Voluntary

First Enlargement June 1, 1986 Board Order - Voluntary

**POOL:** Waskada Lower Amaranth A (03 29A)

This report documents the performance of the Waskada Unit # 8 pressure maintenance project for the period of January 1 to December 31, 2011.

Unit # 8 is part of main Waskada. The Waskada field is situated on the northeast rim of the Williston Basin in southern Manitoba. It comprises a large portion of Township 1 and 2, Ranges 25 and 26 (W1PM).

The Waskada Fields produce light density crude (approximately 36° API), predominantly from the Lower Amaranth formation. The interlaminated, shallow marine to subtidal succession of sandstones, silstones, and shale progressively onlaps the Mississippian unconformity surface from basin center, up dip to the north and eastern basin limits in Saskatchewan and Manitoba. The fine grained reservoir rock has a complex reservoir characterization with 13 to 16 % porosity and permeability on the order of 0.5 to 15 md. The lower Amaranth, the oldest Mesozoic unit is a clastic red bed sequence lying directly on the Paleozoic erosional surface. It consists of a series of dolomitic siltstones and sandstones interbedded with argillaceous siltstones and shales. The section is usually subdivided into a lower sandy unit and an overlying shale unit. The lower sequence is the oil production zone. The bulk of pay is founded in the laminated sandstone/siltstone facies.

The Lower Amaranth has been classified into four general lithological types:

1. Interbedded shale/siltstone/sandstone by grain size, color and texture
2. Siltstone – This lithology occurs in distinct intervals up to two or three meters in thickness. It is generally light green in color and dolomitic.
3. Laminated sandstone – This occurs in distinct sandy intervals with a wide range of grain sizes and primary sedimentary structures.
4. Massive sandstone – This lithology occurs in thin intervals and usually associated with the laminated sandstones facies. Beds are usually light grey to reddish grey in color and coarse to medium – grained.

### **UNIT HISTORY**

#### **Waskada Unit #8 (Unit History)**

<b>Abbreviated Well ID</b>	<b>Date Well Spudded</b>	<b>On Prod YYYY/MM</b>	<b>Org Operator Name</b>	<b>Ground Elevation (m)</b>	<b>TVD (m)</b>
00/01-07-002-25W1/0	8/9/1984	1984/10	Omega Hydcbns Ltd	470.2	919
00/08-07-002-25W1/0	8/12/1984	1984/08	Omega Hydcbns Ltd	469.9	923
00/09-07-002-25W1/0	8/5/1984	1984/08	Omega Hydcbns Ltd	471.6	919
00/16-07-002-25W1/0	8/2/1984	1984/10	Omega Hydcbns Ltd	468.5	924
00/01-08-002-25W1/0	7/7/1984	1984/10	Omega Hydcbns Ltd	472.4	924
00/02-08-002-25W1/0	6/7/1984	1984/06	Omega Hydcbns Ltd	460.5	904
00/03-08-002-25W1/2	7/4/1984	1984/11	NCE Petrofund Corp	472.2	927
02/03-08-002-25W1/0	2/19/2011			473.1	890
00/04-08-002-25W1/0	7/1/1984	1984/08	Omega Hydcbns Ltd	471.4	923
00/05-08-002-25W1/0	10/25/1983	1983/11	Omega Hydcbns Ltd	471.7	905
00/06-08-002-25W1/0	9/21/1983	1983/10	Omega Hydcbns Ltd	473.3	902
00/07-08-002-25W1/0		1983/08	Omega Hydcbns Ltd	472.7	940
00/08-08-002-25W1/2	7/11/1984	1985/05	NCE Petrofund Corp	472.7	920
00/09-08-002-25W1/0	9/17/1983	1983/10	Omega Hydcbns Ltd	473.4	900
00/10-08-002-25W1/0	10/29/1983	1983/11	Omega Hydcbns Ltd	472.7	900
00/11-08-002-25W1/0	7/21/1984	1984/09	Omega Hydcbns Ltd	472.3	924
A0/11-08-002-25W1/0	10/18/1997	1997/11	NCE Rsrcs Grp Inc	473.2	926
00/12-08-002-25W1/0	7/25/1984	1984/11	Omega Hydcbns Ltd	472.8	924
00/13-08-002-25W1/0	7/28/1984	1984/10	Omega Hydcbns Ltd	470.9	919

Abbreviated Well ID	Date Well Spudded	On Prod YYYY/MM	Org Operator Name	Ground Elevation (m)	TVD (m)
00/14-08-002-25W1/0	6/11/1984	1984/08	Omega Hydcbns Ltd	471.1	907
00/15-08-002-25W1/0	7/17/1984	1984/10	Omega Hydcbns Ltd	474.3	915
00/16-08-002-25W1/0	7/14/1984	1984/07	Omega Hydcbns Ltd	473.4	921

## Waskada Unit #8 (Production & Injection History)

Abbreviated Well ID	First Prod YYYY/MM	On Inject. YYYY/MM	Last Prod. YYYY/MM	Cumulative OIL Prod. (m3)	Cumulative WTR Prod. (m3)	First 12 mo. Ave WC%	Last Inject. YYYY/MM
00/01-07-002-25W1/0	1984/10		1989/04	237	253	22.1	
00/08-07-002-25W1/0	1984/08		2010/11	9603	1963	8.6	
00/09-07-002-25W1/0	1984/08		2010/11	12993	2313	13.4	
00/16-07-002-25W1/0	1984/10		1996/06	5007	4593	28.2	
00/01-08-002-25W1/0	1984/10		1988/08	785	985	53.4	
00/02-08-002-25W1/0	1984/06		1998/02	3319	1474	12.2	
00/03-08-002-25W1/2	1984/11		2011/07	10211	8563	52.8	
02/03-08-002-25W1/0							
00/04-08-002-25W1/0	1984/08		2010/11	23335	7754	2.6	
00/05-08-002-25W1/0	1983/11	1985/10	1985/09	1970	1928	39.7	2006/06
00/06-08-002-25W1/0	1983/10		2010/11	14842	3070	2.6	
00/07-08-002-25W1/0	1983/08	1986/11	1986/10	5593	133	3.3	2006/11
00/08-08-002-25W1/2	1985/05		2010/10	2226	1191	12	
00/09-08-002-25W1/0	1983/10		1996/07	3911	2219	34.7	
00/10-08-002-25W1/0	1983/11		2000/09	13259	11600	1.2	
00/11-08-002-25W1/0	1984/09		2011/07	20103	6612	30.3	
A0/11-08-002-25W1/0	1997/11		2010/11	4985	776	7.7	
00/12-08-002-25W1/0	1984/11		1996/07	2257	1900	51.5	
00/13-08-002-25W1/0	1984/10	1985/10	1985/09	122	65	34.9	2006/06

Abbreviated Well ID	First Prod YYYY/MM	On Inject. YYYY/MM	Last Prod. YYYY/MM	Cumulative OIL Prod. (m3)	Cumulative WTR Prod. (m3)	First 12 mo. Ave WC%	Last Inject. YYYY/MM
00/14-08-002-25W1/0	1984/08		2011/11	18913	2400	3.1	
00/15-08-002-25W1/0	1984/10	1985/10	1985/09	545	373	40.6	2011/11
00/16-08-002-25W1/0	1984/07		2011/03	19743	5747	9.6	

## **DISCUSSION:**

### **Production Performance**

Production Response versus Injection: Since injection began, early 1985, injection rates fluctuated to some degree amongst the injectors; it is difficult to link any production responses to any specific injector. Although injection rate was high recently, it did not affect the produced oil and water.

### **Voidage Replacement Ratio Calculation**

What could be described as very limited success, the waterflood was not maintained properly and injection rate was dropped year after year in most cases, and then increased. The cumulative VRR in the pool is about 1.57 and current monthly VRR is very high. This can be misleading, from one hand, as the injection across the pool is quite variable, and from other hand it is unknown how much of this water lost to Mission Canyon Formation, located just below the Amaranth Formation.

To understand the past performance of the Lower Amaranth waterflood, we are doing some reservoir engineering work to come up with potential solutions. One of our plans is to do a pilot plan in section 2: The objective of the pilot is to:

1. See if can we can inject water continuously into the Lower Amaranth Formation
  - i. Particle size less than 1 micron
  - ii. Total Suspended Solid (TSS) less than 10 ppm
  - iii. Oil less than 10 ppm
2. Inject below the frac pressure
3. Test the simulation model that we have built.

### 2011 Waskada Lower Amaranth Waterflood Pilot Location

The pilot producer will be 102/12-01-02-26W1/00 (The horizontal well) and the injectors will be two vertical wells; 100/12-01-02-26W1 and 100/11-01-02-26 (need to be converted to injectors)

### **Corrosion and Scale Prevention Program**

We currently inject ScalCor down all the new horizontal wells. Plus, PennWest will be installing cathodic protection on the wells. Also, the new gathering system is Fiberglass and as such is not susceptible to corrosion.

## **SUMMARY AND RECOMMENDATIONS**

### **[Producers]**

#### **Current Producing Wells**

1. 00/08-07-002-25W1/0
2. 00/09-07-002-25W1/0
3. 00/04-08-002-25W1/0
4. 00/06-08-002-25W1/0
5. A0/11-08-002-25W1/0
6. 00/14-08-002-25W1/0

#### **Current Suspended Wells**

1. 00/03-08-002-25W1/2 (since 2011/07)
2. 00/11-08-002-25W1/0 (since 2011/07)
3. 00/16-08-002-25W1/0 (since 2011/03)

### **Abandoned Wells**

1. 00/01-07-002-25W1/0 (since 1989/05)
2. 00/16-07-002-25W1/0 (since 1996/07)
3. 00/01-08-002-25W1/0 (since 1988/09)
4. 00/02-08-002-25W1/0 (since 1998/03)
5. 00/09-08-002-25W1/0 (since 1996/08)
6. 00/10-08-002-25W1/0 (since 2000/10)
7. 00/12-08-002-25W1/0 (since 1996/08)

### **[Injectors]**

### **Current Injecting Wells**

1. 00/15-08-002-25W1/0

### **Current Suspended Wells**

1. 00/05-08-002-25W1/0 (since 2006/07)
2. 00/13-08-002-25W1/0 (since 2006/07)

### **Abandoned Wells**

1. 00/07-08-002-25W1/0 (since 2006/12)

The behavior of a Waskada Unit 8 producers are indicated by examining the oil rate versus time plots (see Appendix B). Unit 8 exhibited relatively high initial oil productivity (most of the wells that drilled in the past were verticals), rapidly declining to flat/low decline rates, with almost no discernible water flood response. This behavior can be explained by drop in the reservoir pressure from initial (approximately 8700 kPag) to above in some wells or below in others bubble point pressure (about 4200 kPag) followed by solution gas breakout which adversely affected the relative permeability to oil. (see Table # 2)

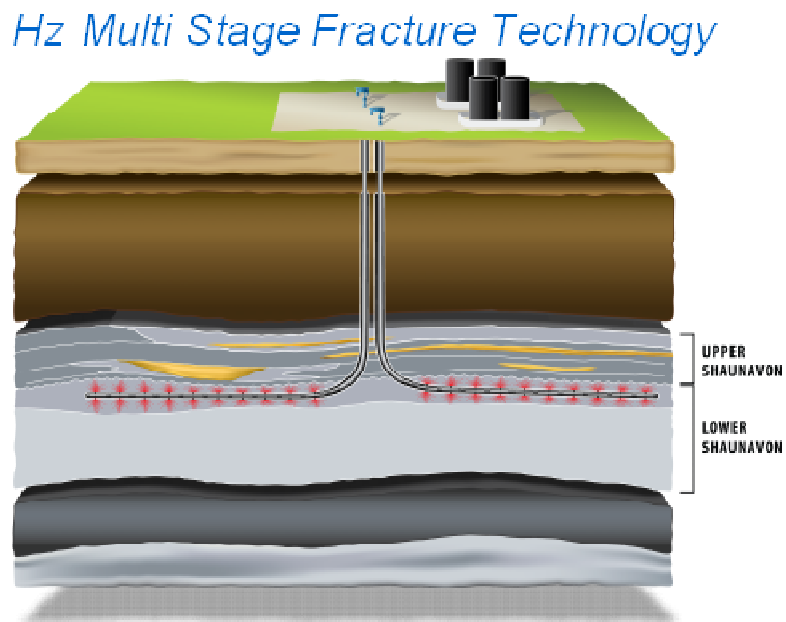
Also, it is believed that fracture stimulation treatments, performed on these wells prior to initiation of water injection, “broke” through into the higher productivity Mississippian



zone and that majority of injected water to date has entered this zone. This is one of the major explanations for lack of waterflood response to date and the continued decline in oil productivities.

The Waskada Lower Amaranth is becoming a non-conventional tight oil resources play that utilizes horizontal multi-stage frac drilling technology (small multi-stage frac stimulations on newly drilled wells will remain “in zone” within the Lower Amaranth) to re-develop the thick low perm oil zones adjacent to the conventional Amaranth zone that was discovered in the 1980’s. PennWest drilled a horizontal well in 2011; the location is 102/03-08-002-25W1. PennWest’s follow up plan is to drill more horizontal wells in the unit, convert some of the recent horizontal producing wells to injection wells to increase the sweep efficiency and ultimately increase the recoverable oil in place.

The following is the HZ Multi Stage Fracture Technology development plan that we are using:



**TABLES****Waskada Unit #8****Table 1: Rate History**

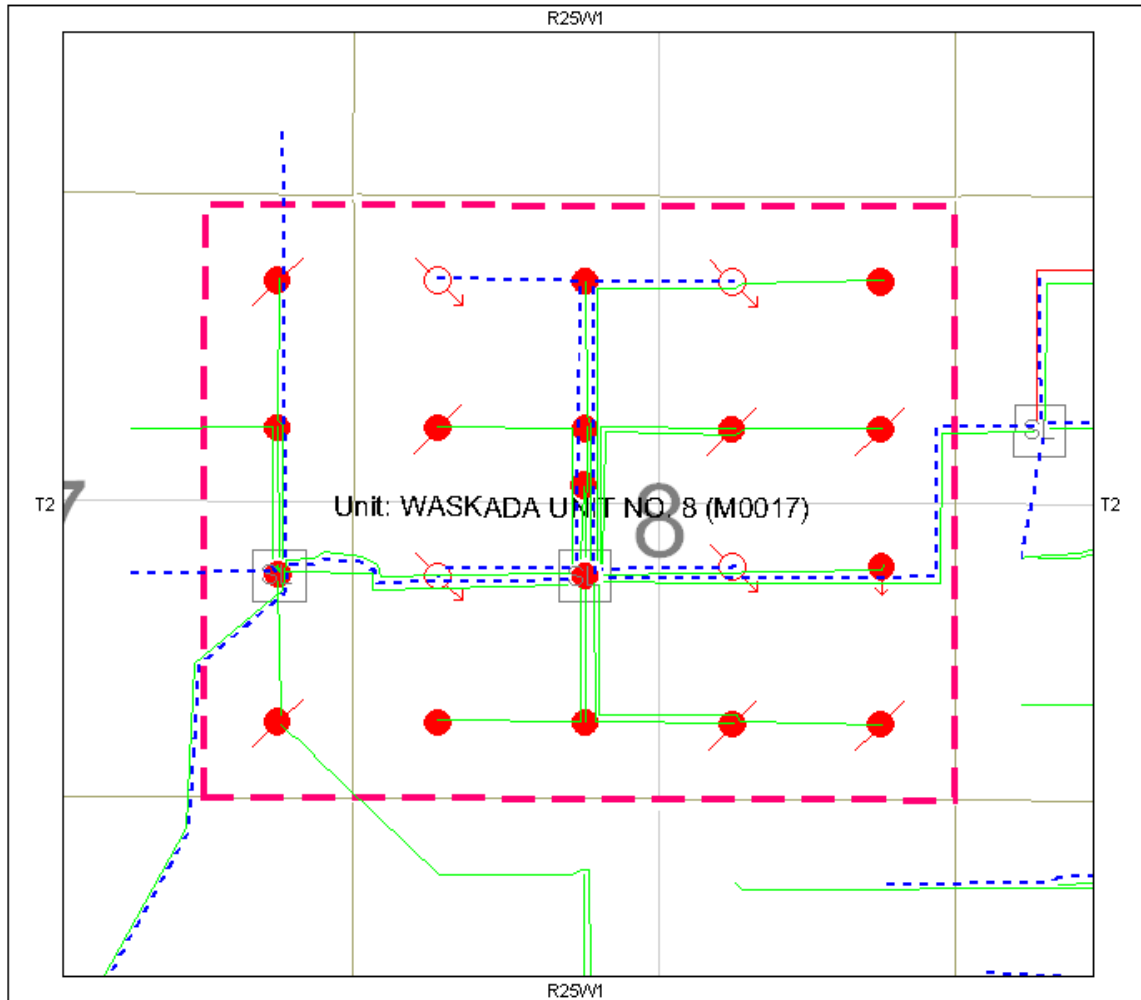
Date	Oil		Water		Inj Water	
Year	m3/year	m3/day	m3/year	m3/day	m3/year	m3/day
1983	1,072	2.94	235	0.64	0	0.00
1984	9,163	25.10	1,921	5.26	0	0.00
1985	20,803	56.99	6,068	16.62	11,348	31.09
1986	16,539	45.31	3,806	10.43	57,395	157.25
1987	14,757	40.43	2,561	7.02	47,134	129.14
1988	11,954	32.75	4,154	11.38	18,592	50.94
1989	11,607	31.80	4,748	13.01	9,878	27.06
1990	9,024	24.72	4,501	12.33	11,526	31.58
1991	8,145	22.31	3,456	9.47	13,196	36.15
1992	7,267	19.91	3,223	8.83	14,976	41.03
1993	6,629	18.16	2,172	5.95	31,660	86.74
1994	5,332	14.61	2,716	7.44	11,248	30.82
1995	5,152	14.12	4,522	12.39	12,639	34.63
1996	4,673	12.80	2,289	6.27	14,502	39.73
1997	4,846	13.28	1,641	4.50	11,958	32.76
1998	5,388	14.76	1,312	3.59	8,507	23.31
1999	4,273	11.71	1,511	4.14	7,544	20.67
2000	4,499	12.33	1,830	5.01	5,226	14.32
2001	3,787	10.38	1,633	4.47	5,778	15.83
2002	2,960	8.11	1,502	4.12	5,645	15.47
2003	2,635	7.22	1,268	3.47	5,693	15.60
2004	2,273	6.23	1,002	2.74	5,628	15.42
2005	2,022	5.54	1,230	3.37	4,674	12.81
2006	1,959	5.37	1,500	4.11	8,710	23.86
2007	1,568	4.30	1,101	3.02	1,867	5.12
2008	1,590	4.35	1,771	4.85	31,376	85.96
2009	1,649	4.52	1,182	3.24	24,265	66.48
2010	1,325	3.63	842	2.31	55,871	153.07
2011	1,070	4.22	218	0.84	29,470	80.74

**Table 2: Pressure Surveys**


<b>Location</b>	<b>Shut In Date</b>	<b>Date of Survey</b>	<b>Type of Survey</b>	<b>Pressure @ Datum Depth (kPa)</b>
00/04-08-002-25W1/0	29-Nov-06	11-Dec-06	Acoustic Build Up	2857
00/05-08-002-25W1/0	Nov-89	(334 days)	Static Gradient	8297
00/13-08-002-25W1/0	Jan-91	(20 days)	Static Gradient	9170

## **APPENDIX A**

## Appendix A – Area Map

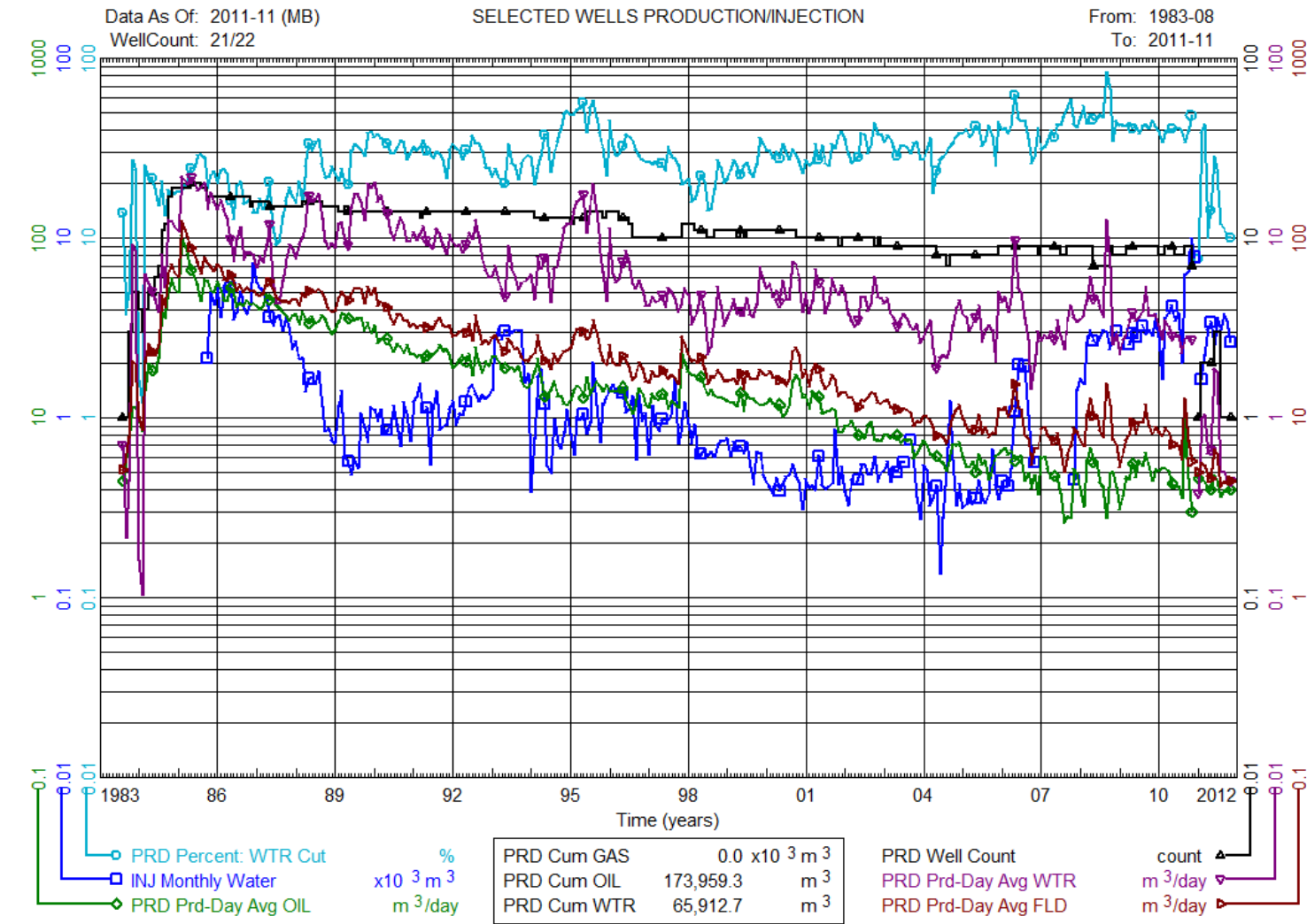


WELL SYMBOLS									
• OIL	✂ AO	⊕ PTN	⊕ D&A	⊕ WI					
○ LCT	⊕ AWI	⊕ STN	⊕ CMM	⊕ DRL					
⊕ RDR	⊕ WD	⊕ AWS	⊕ AWD	⊕ SWI					
⊕ SO	⊕ WSC	⊕ J&A	□ SL						

<b>PennWest</b> Exploration		
Waskada Unit #8		
	By :	Date : 2011/04/14
	Scale = 1:14473	Project : Waskada

## **APPENDIX B**

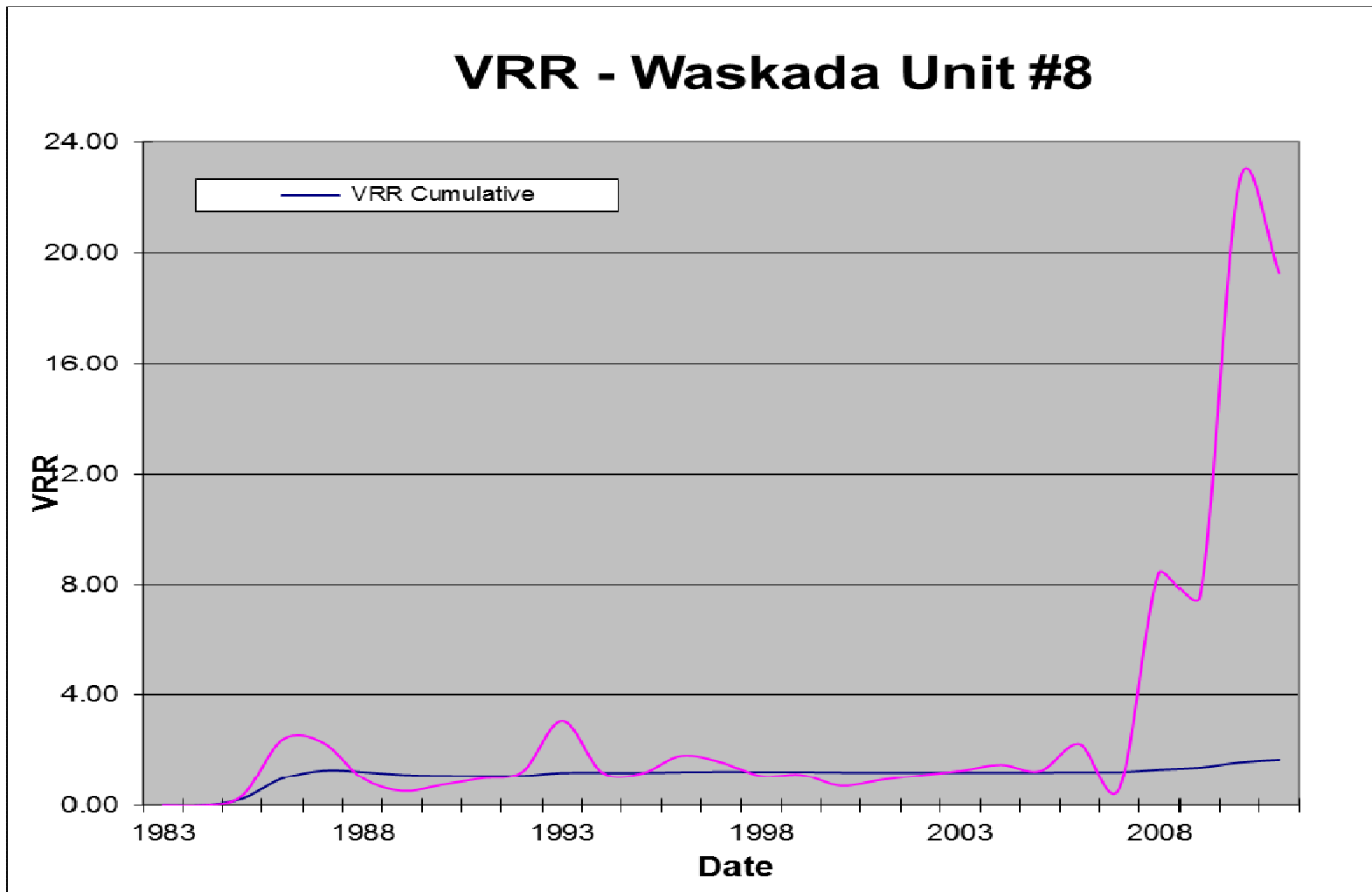
## Appendix B – Production and Injection History plot



## **APPENDIX C**

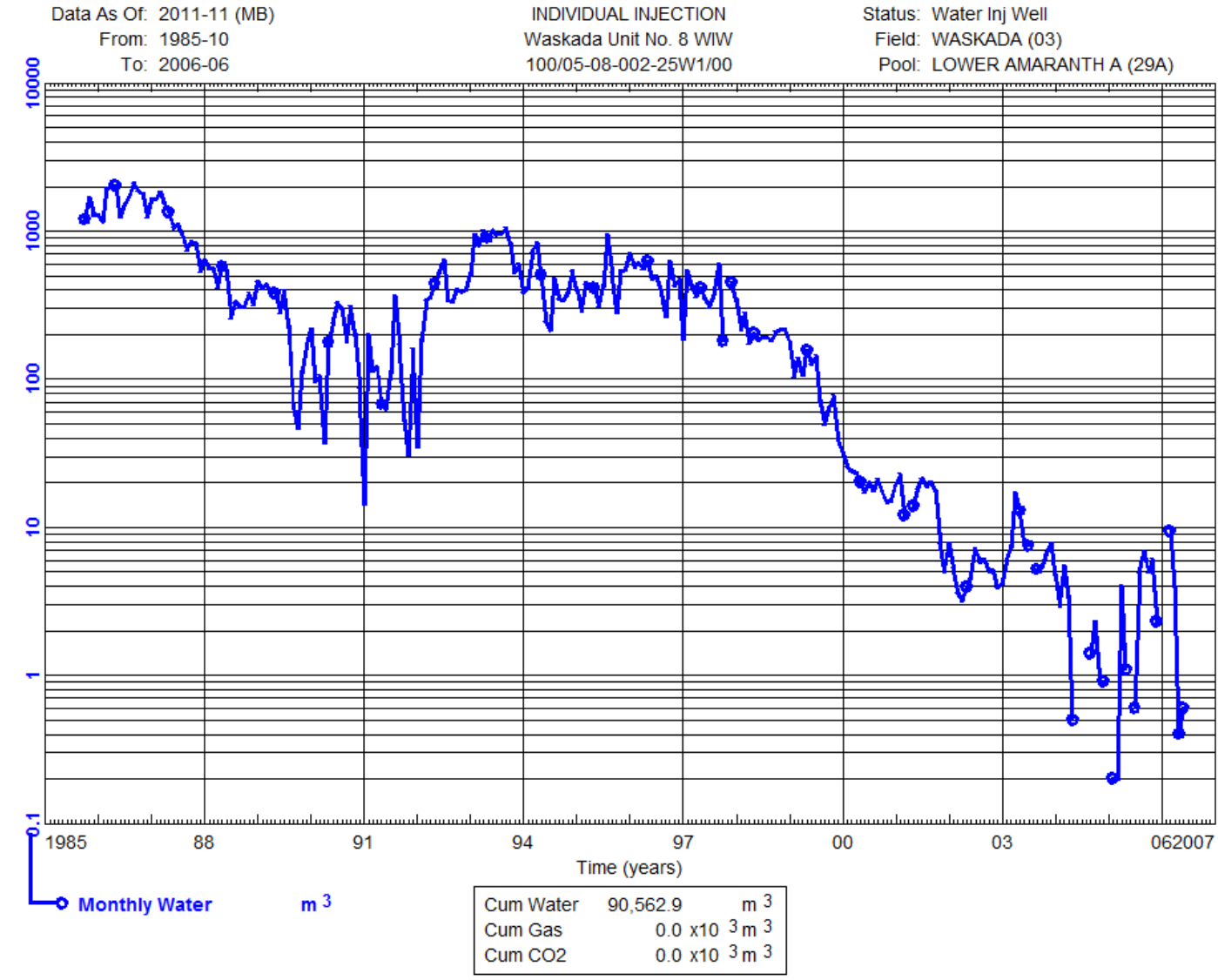


## Appendix C – Voidage Replacement Ratio VRR



## **APPENDIX D**

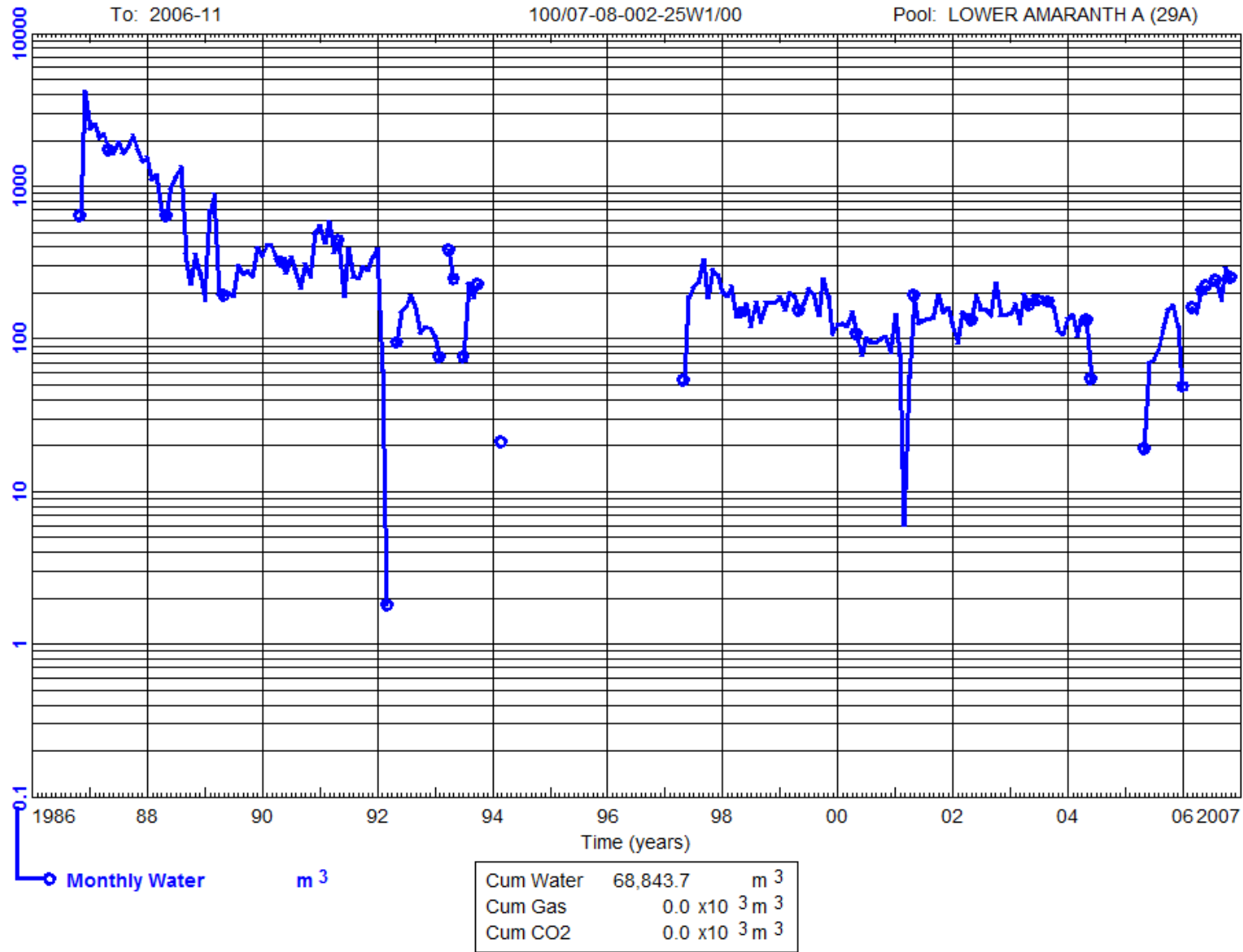
## Appendix D – Production and Injection Profiles (Individual wells)



Data As Of: 2011-11 (MB)  
From: 1986-11  
To: 2006-11

INDIVIDUAL INJECTION  
Penn West Waskada SWD  
100/07-08-002-25W1/00

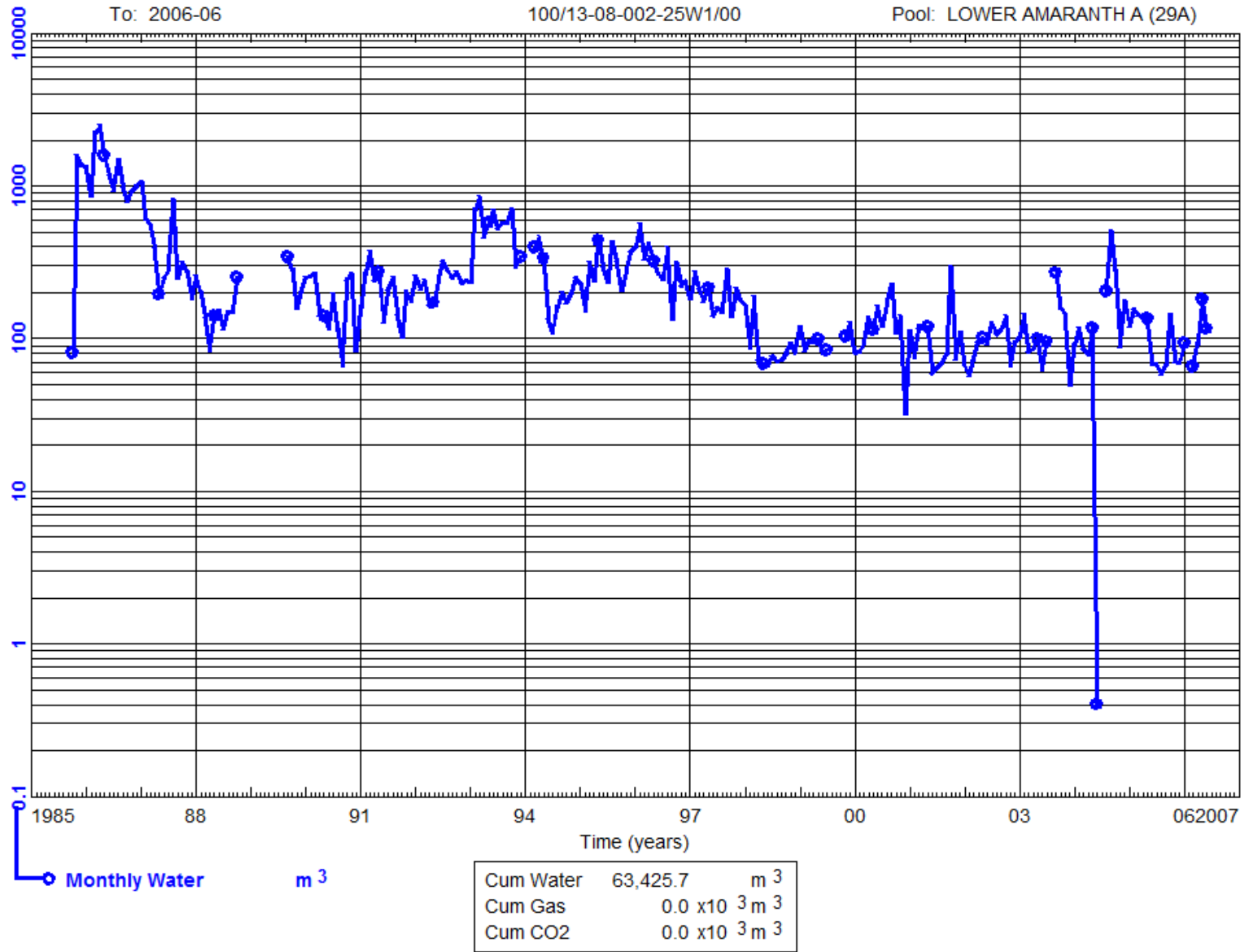
Status: Abandoned Water Inj Well  
Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
From: 1985-10  
To: 2006-06

INDIVIDUAL INJECTION  
Waskada Unit No. 8 WIW  
100/13-08-002-25W1/00

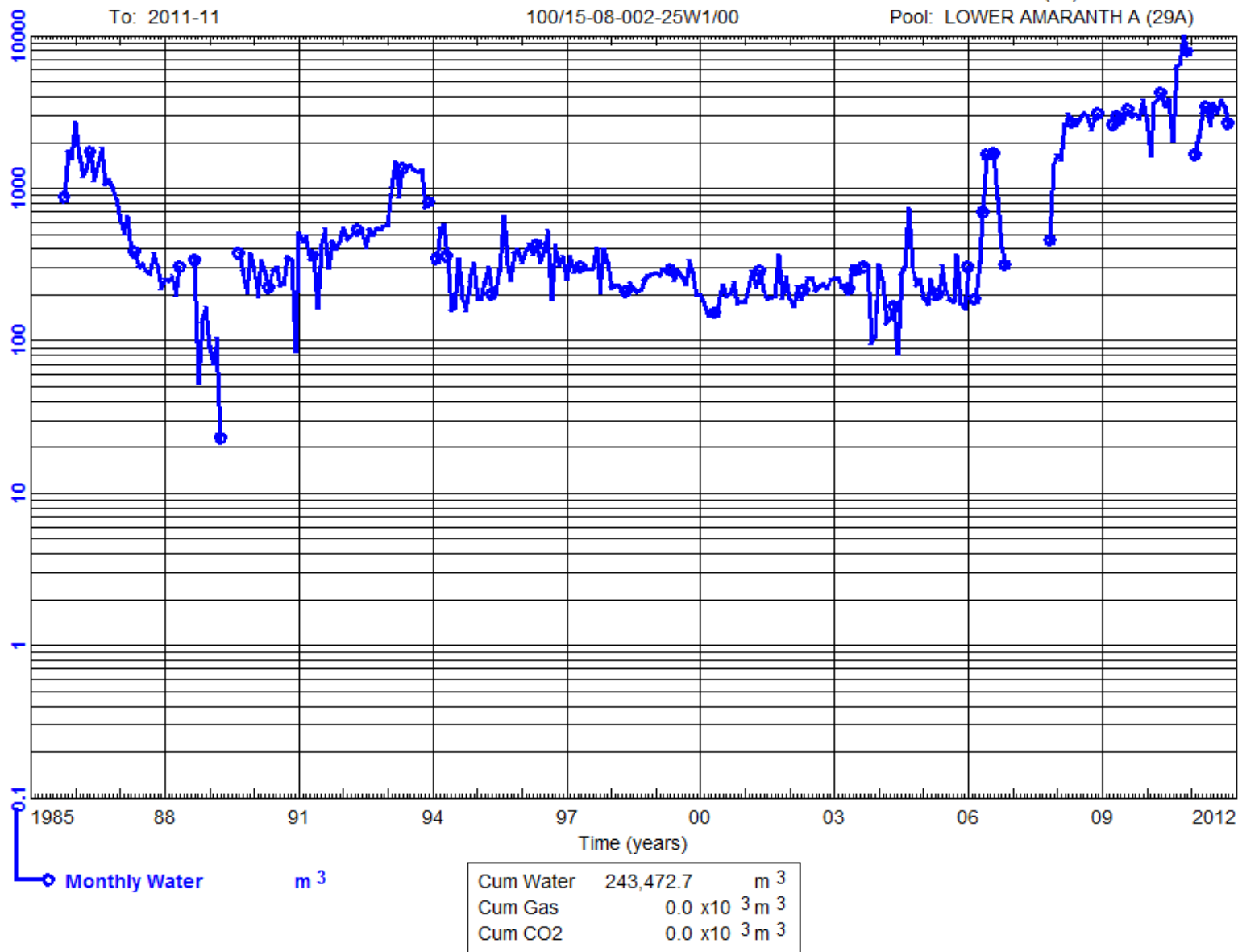
Status: Water Inj Well  
Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
From: 1985-10  
To: 2011-11

INDIVIDUAL INJECTION  
Waskada Unit No. 8 WIW  
100/15-08-002-25W1/00

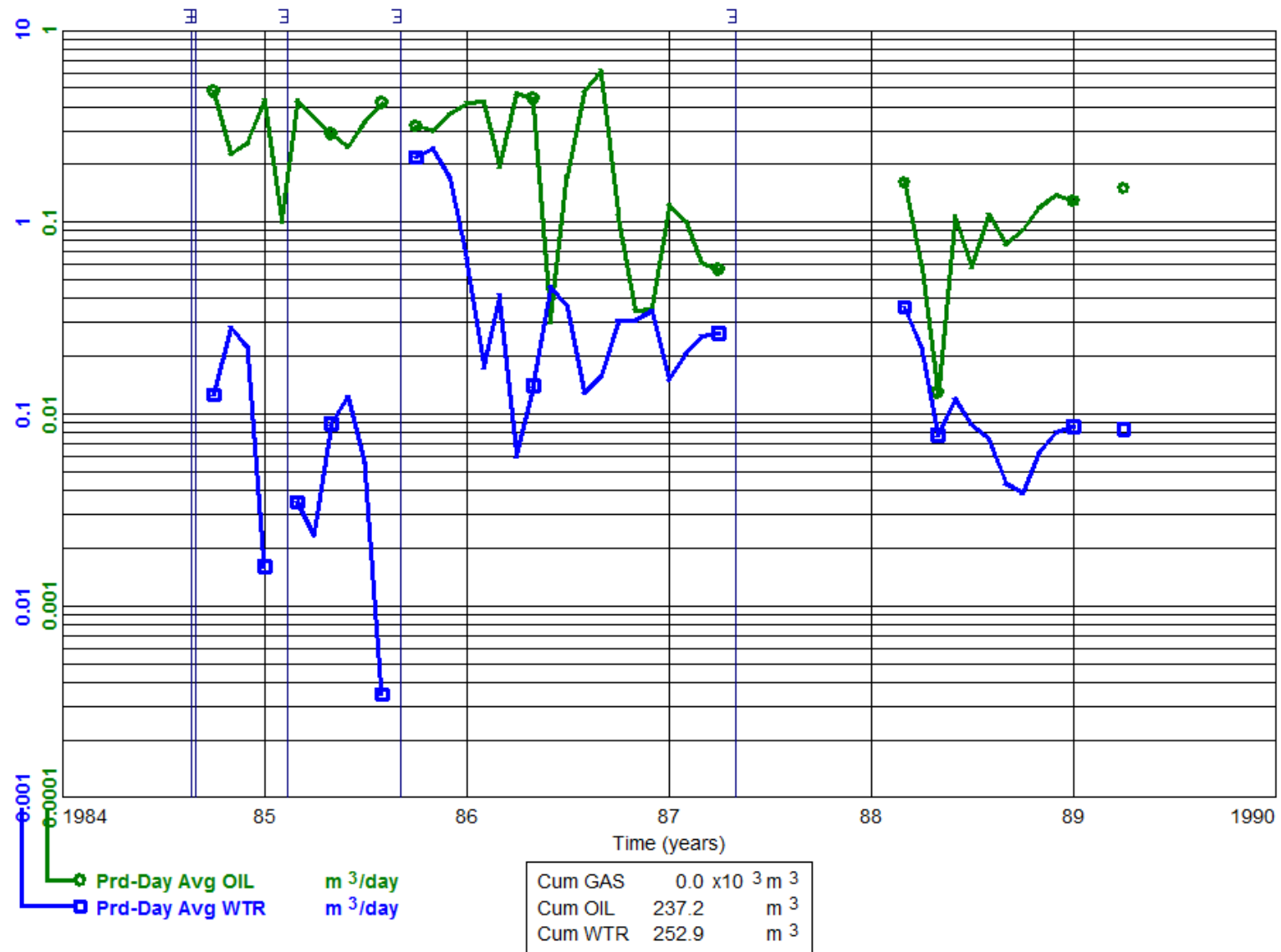
Status: Water Inj Well  
Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-10  
 To: 1989-04

INDIVIDUAL PRODUCTION  
 Omega Waskada  
 100/01-07-002-25W1/00

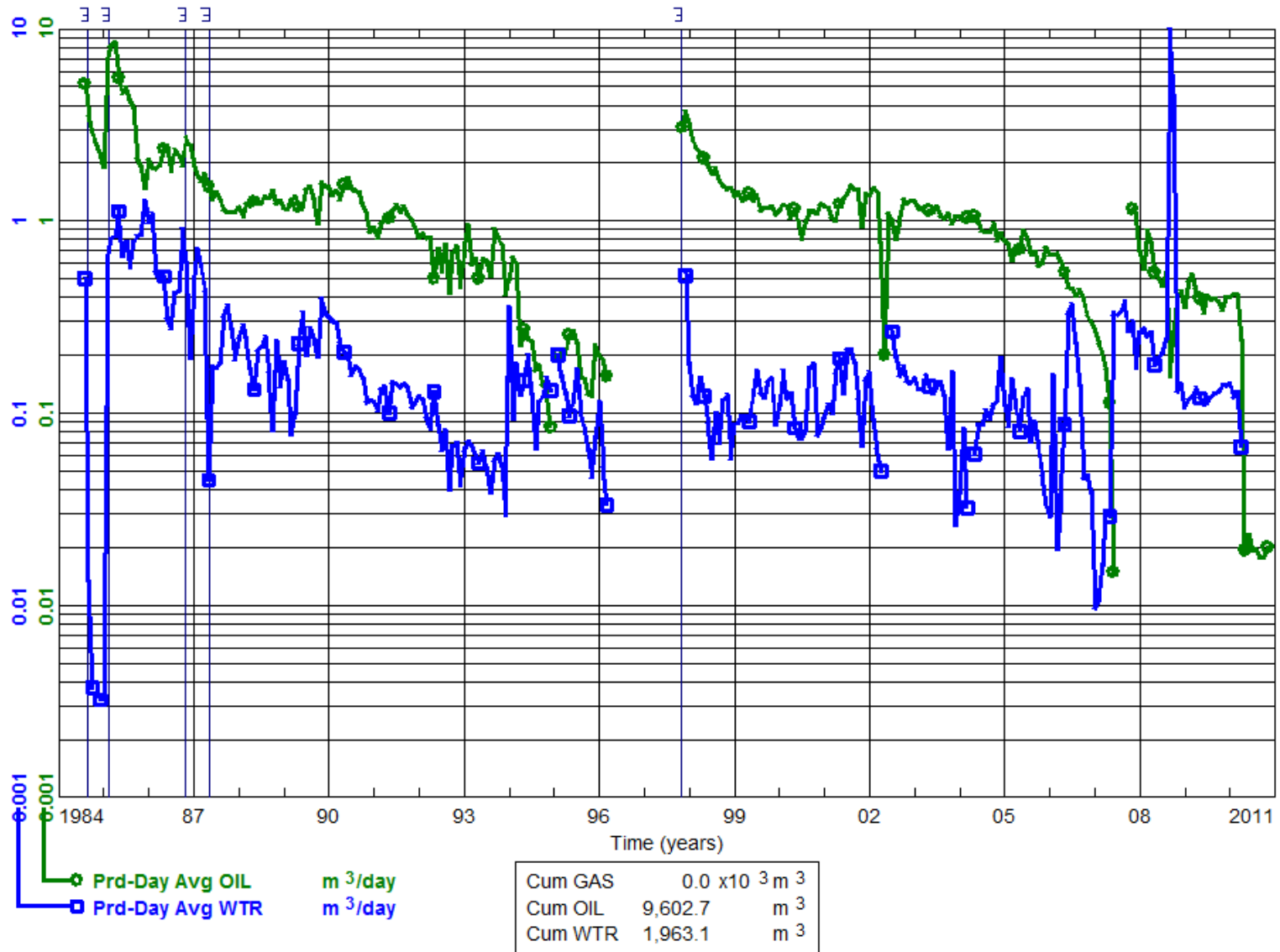
Status: Abandoned Producer  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
From: 1984-08  
To: 2010-11

INDIVIDUAL PRODUCTION  
Waskada Unit No. 8  
100/08-07-002-25W1/00

Status: Capable Of Oil Prod  
Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)

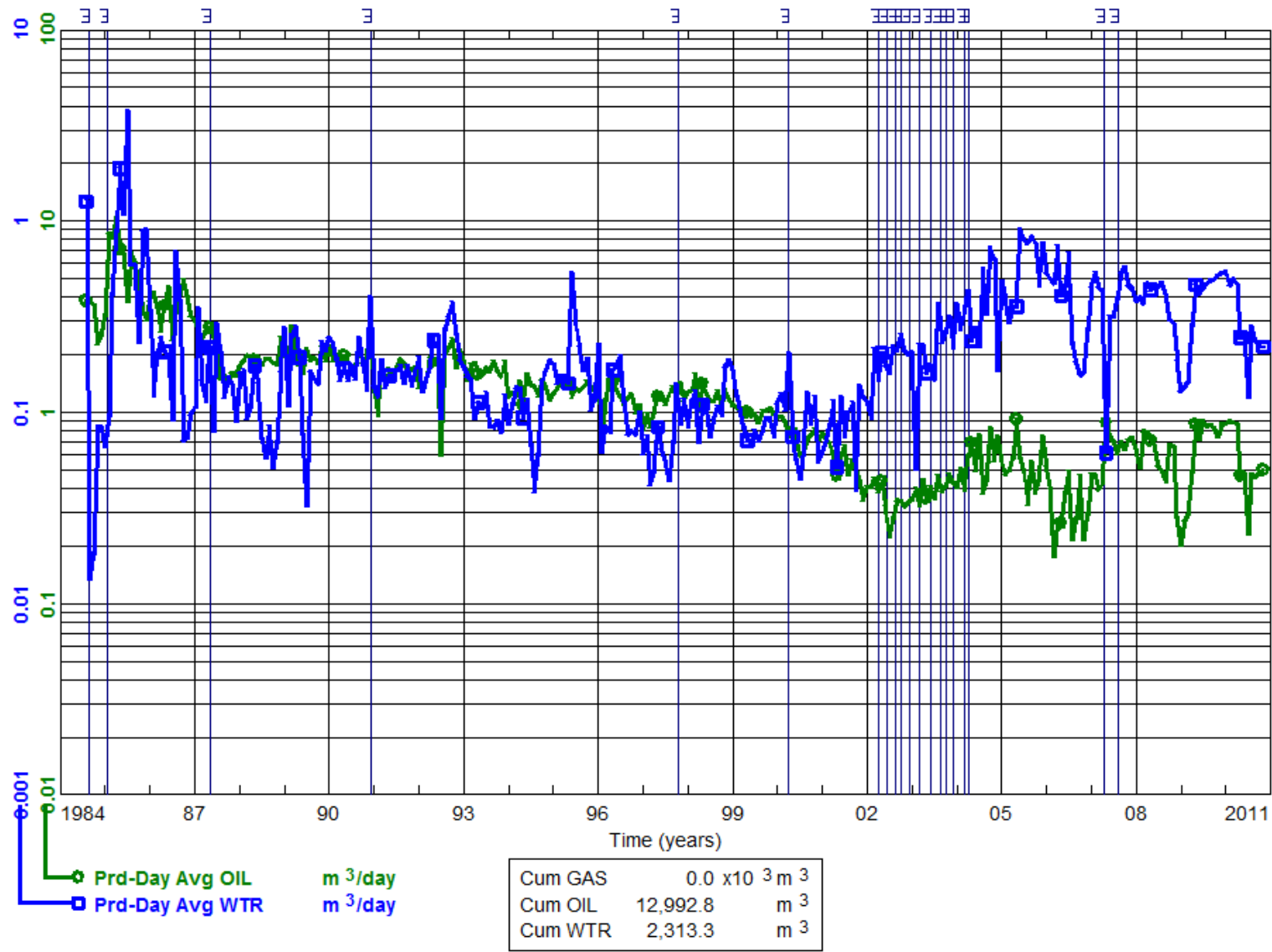




Data As Of: 2011-11 (MB)  
 From: 1984-08  
 To: 2010-11

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/09-07-002-25W1/00

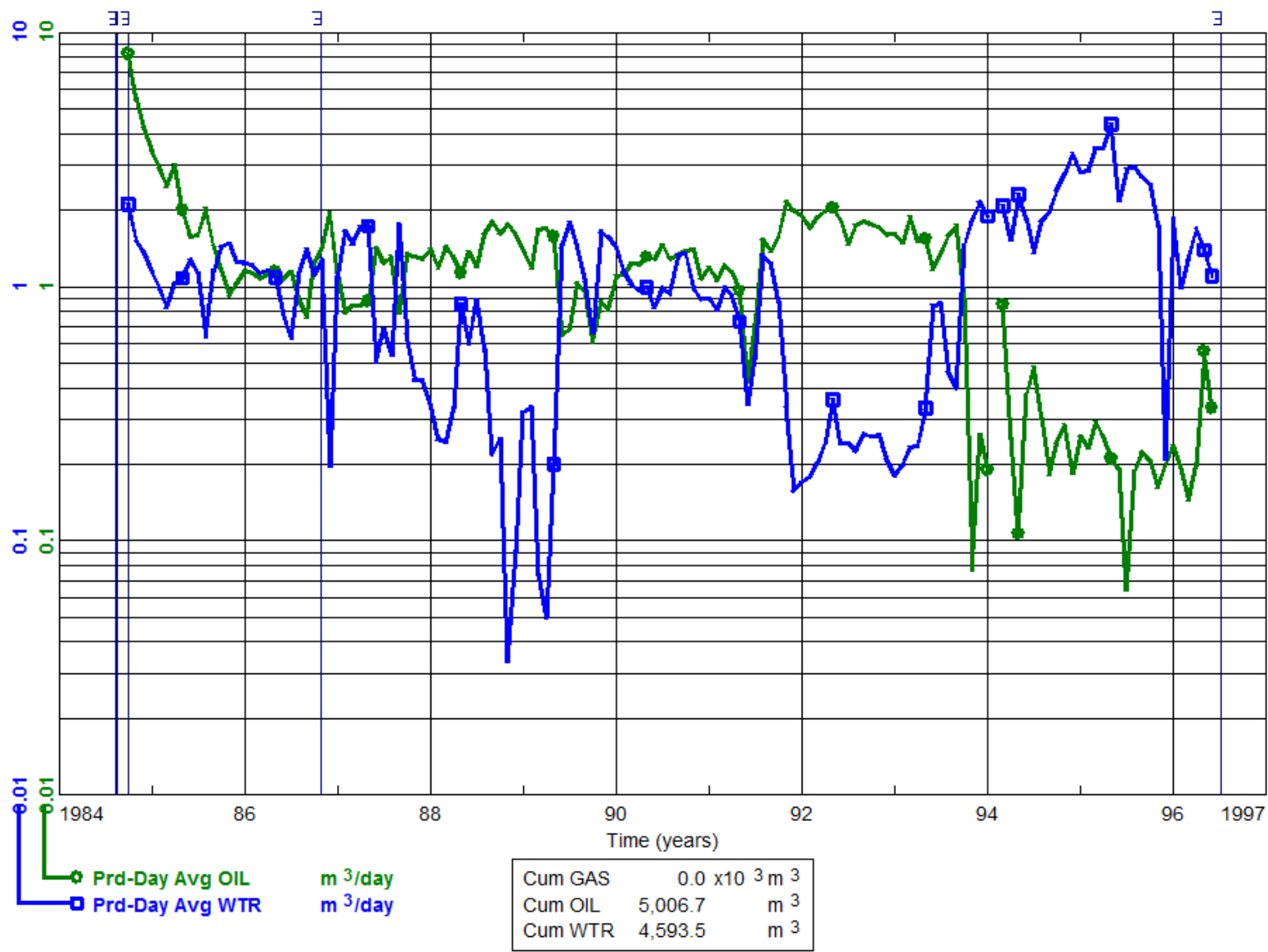
Status: Capable Of Oil Prod  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-10  
 To: 1996-06

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/16-07-002-25W1/00

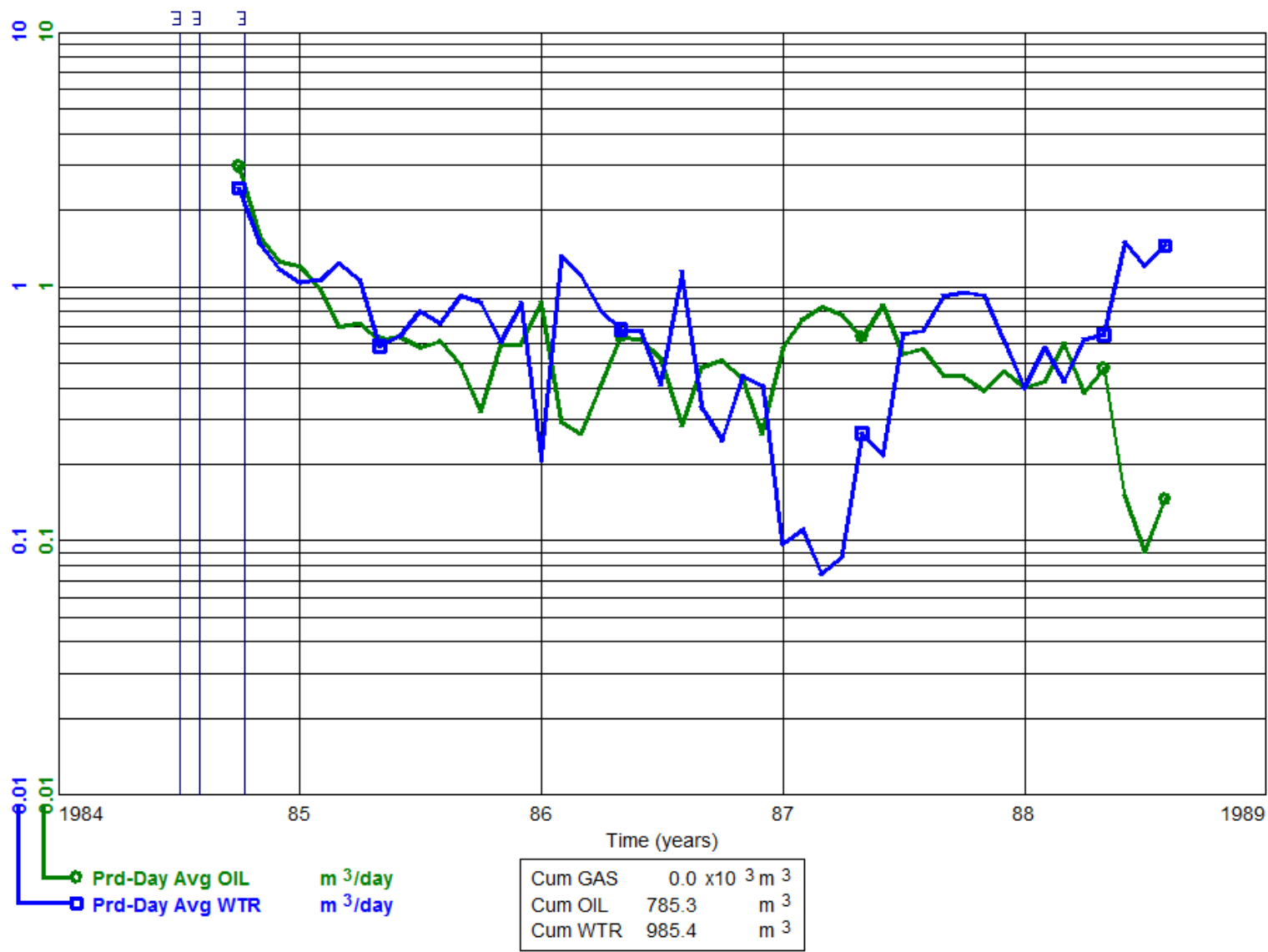
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 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-10  
 To: 1988-08

INDIVIDUAL PRODUCTION  
 Omega Waskada  
 100/01-08-002-25W1/00

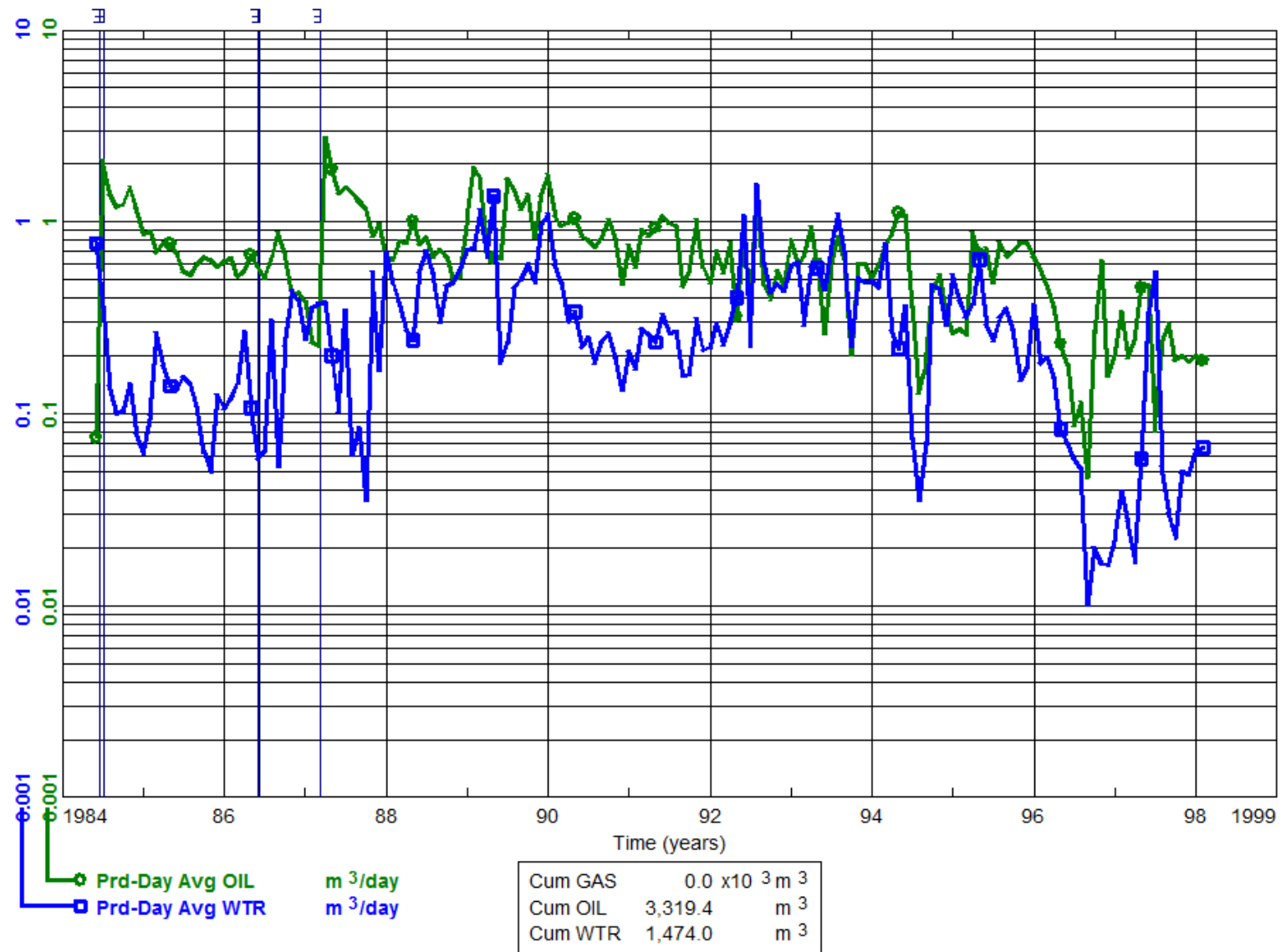
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 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
From: 1984-06  
To: 1998-02

INDIVIDUAL PRODUCTION  
Waskada Unit No. 8  
100/02-08-002-25W1/00

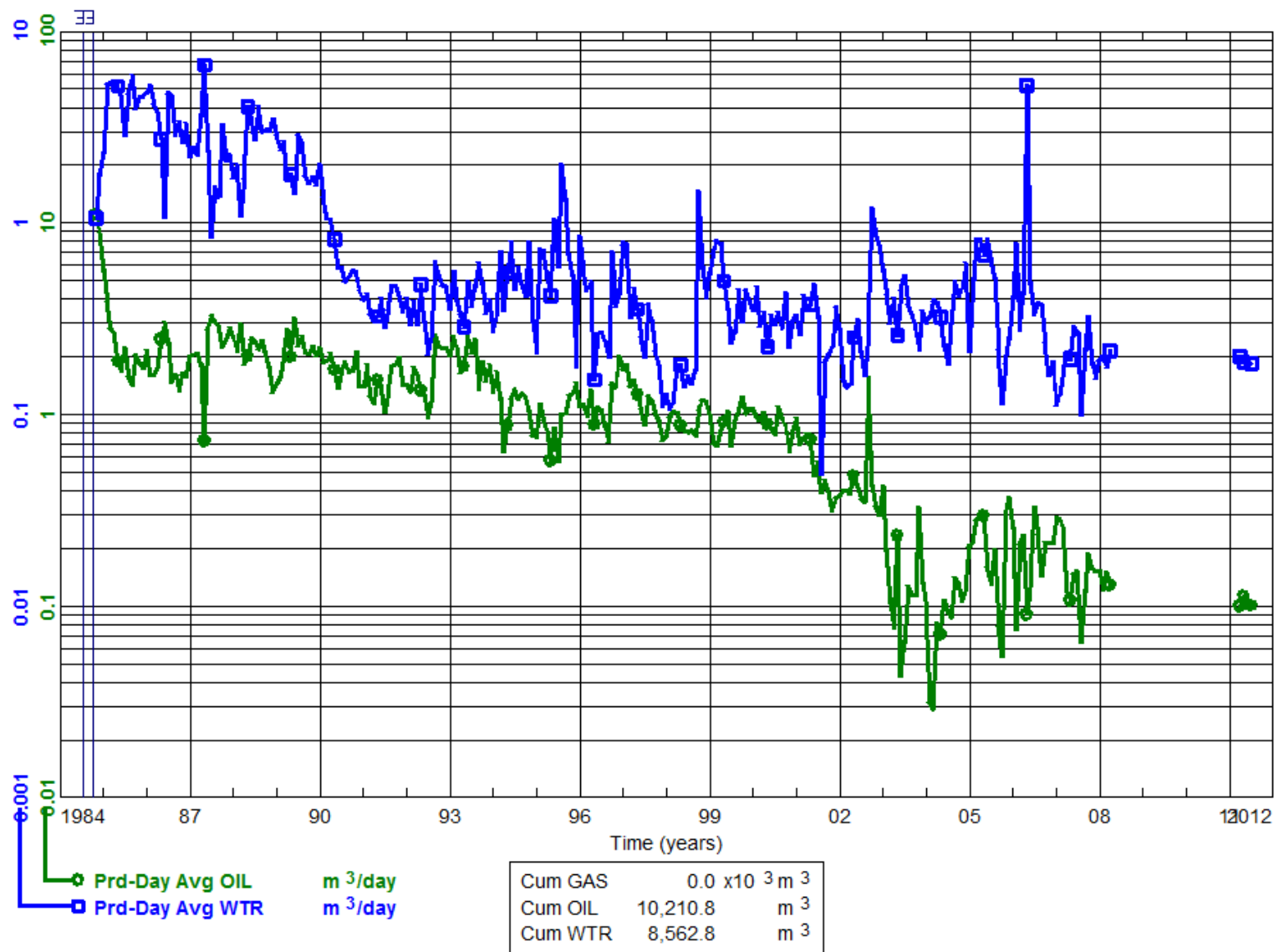
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Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-11  
 To: 2011-07

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/03-08-002-25W1/02

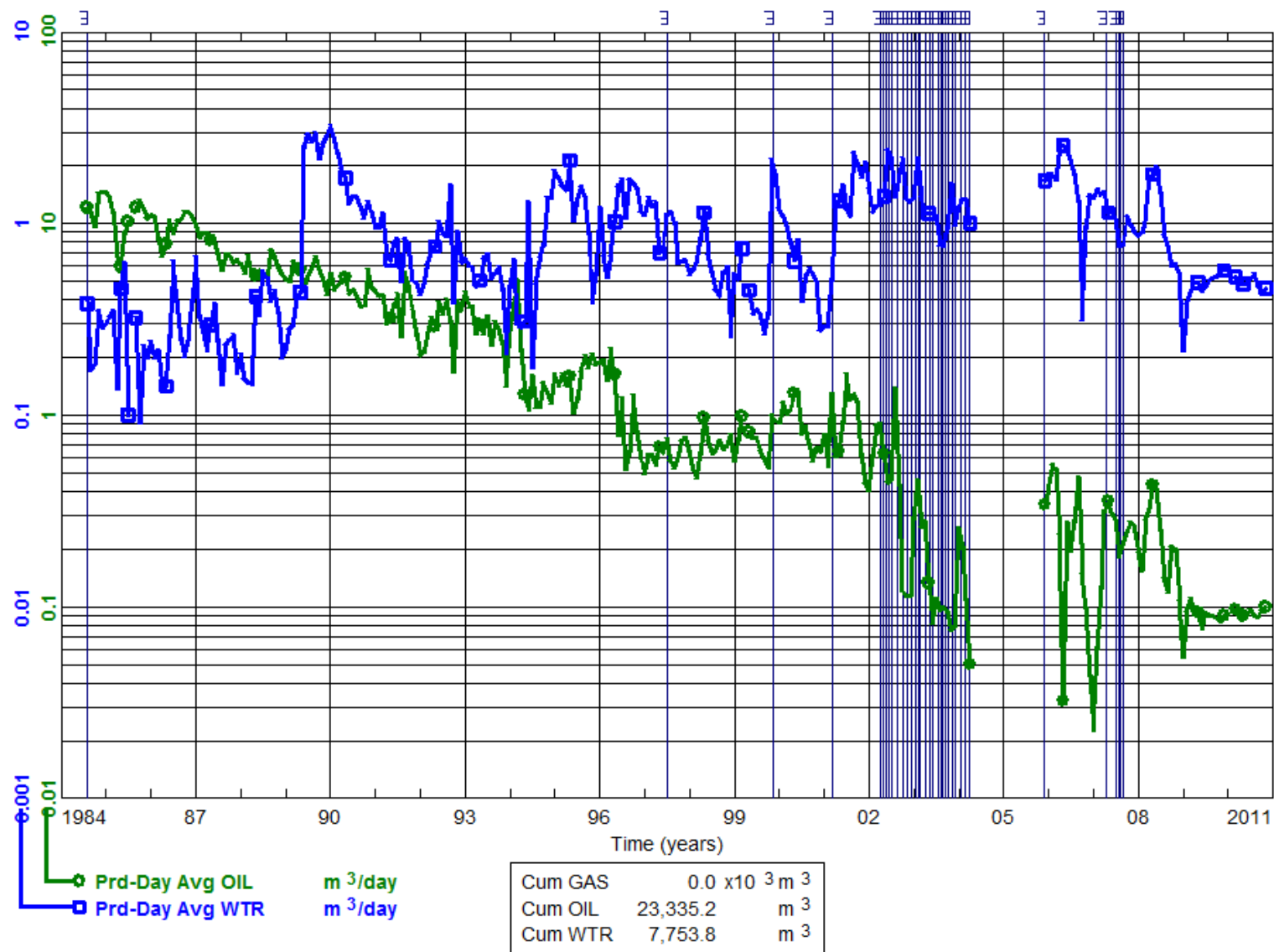
Status: Capable Of Oil Prod  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-08  
 To: 2010-11

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/04-08-002-25W1/00

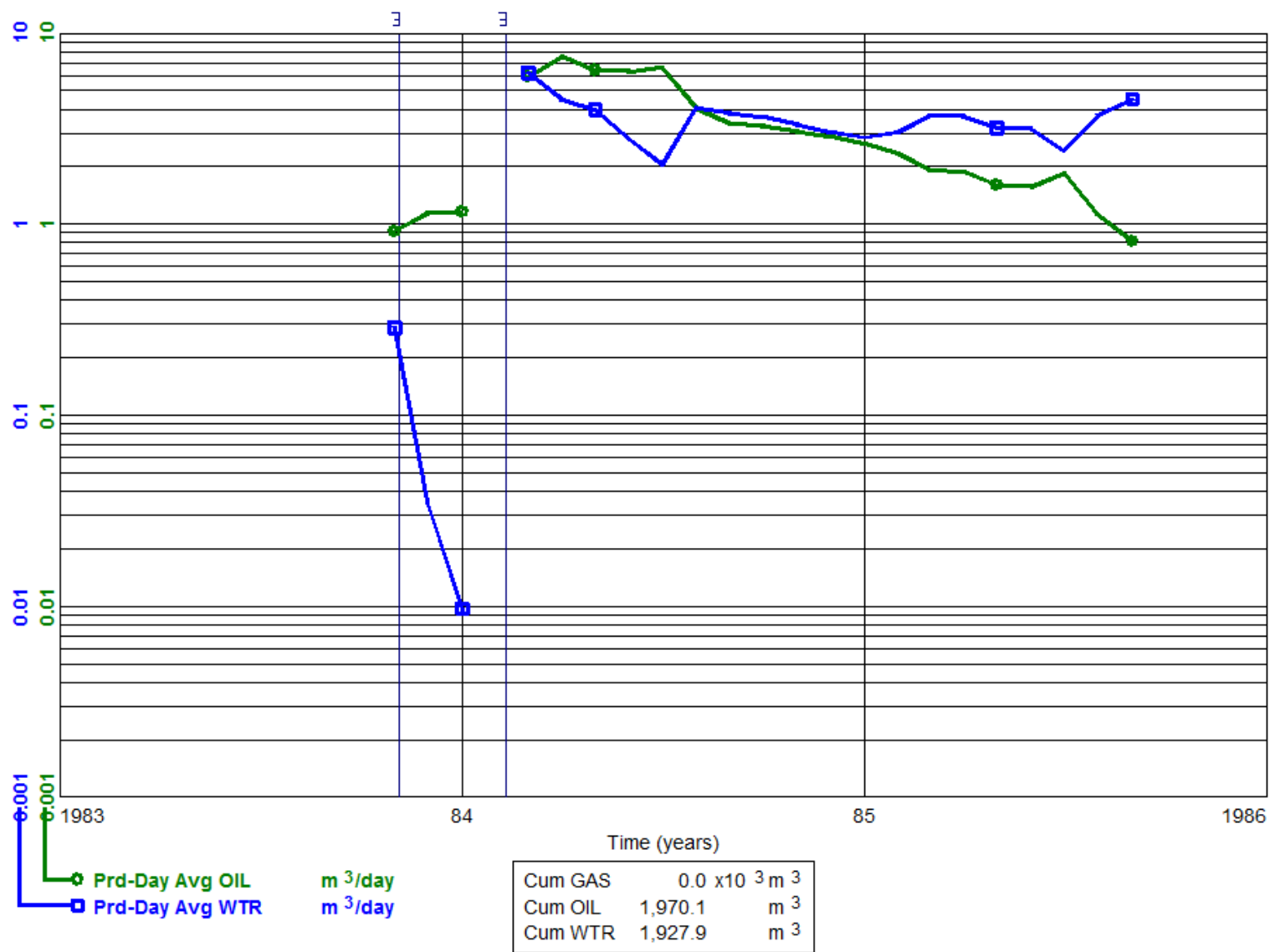
Status: Capable Of Oil Prod  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1983-11  
 To: 1985-09

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8 WIW  
 100/05-08-002-25W1/00

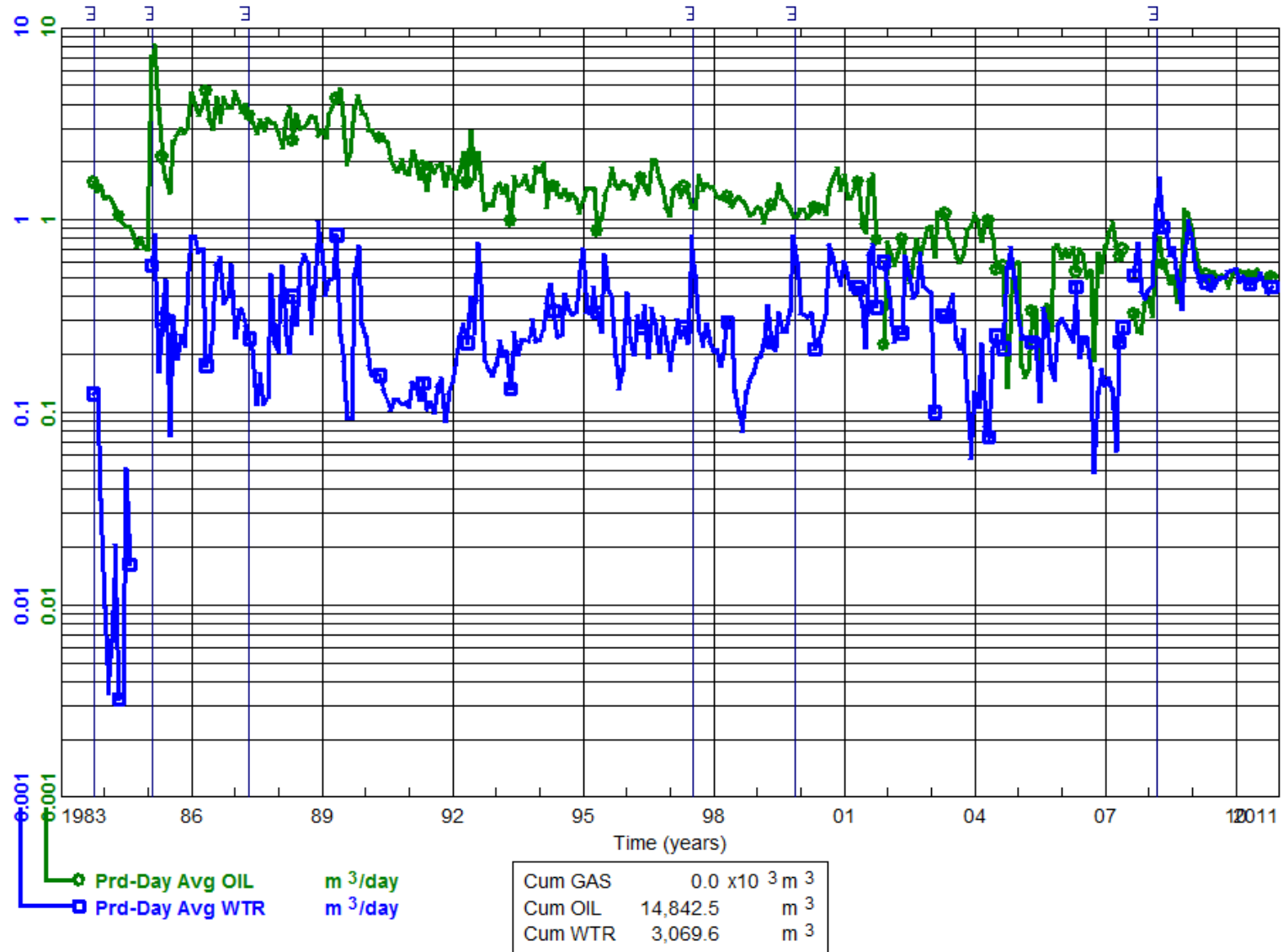
Status: Water Inj Well  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1983-10  
 To: 2010-11

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/06-08-002-25W1/00

Status: Capable Of Oil Prod  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)

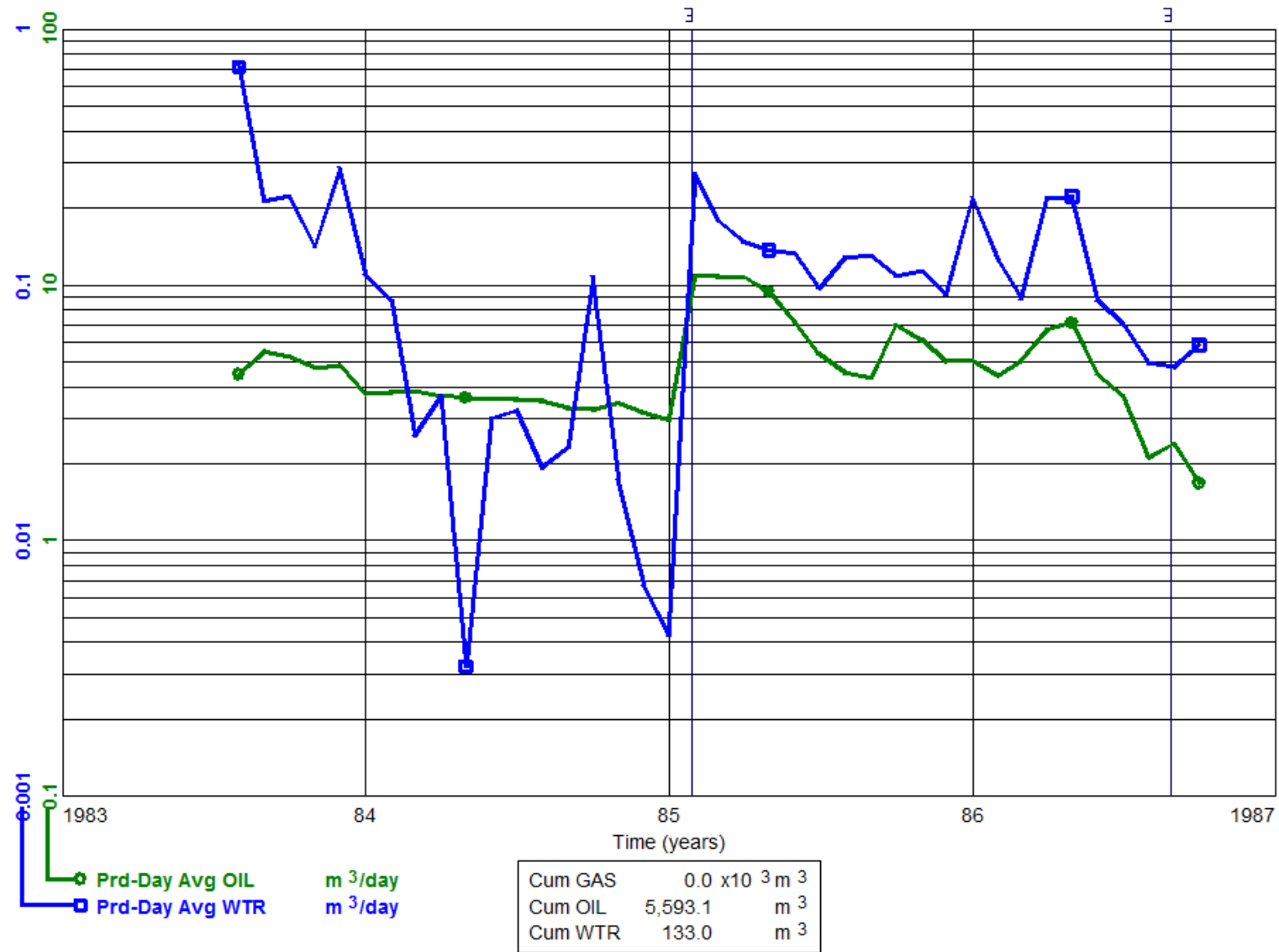




Data As Of: 2011-11 (MB)  
From: 1983-08  
To: 1986-10

INDIVIDUAL PRODUCTION  
Penn West Waskada SWD  
100/07-08-002-25W1/00

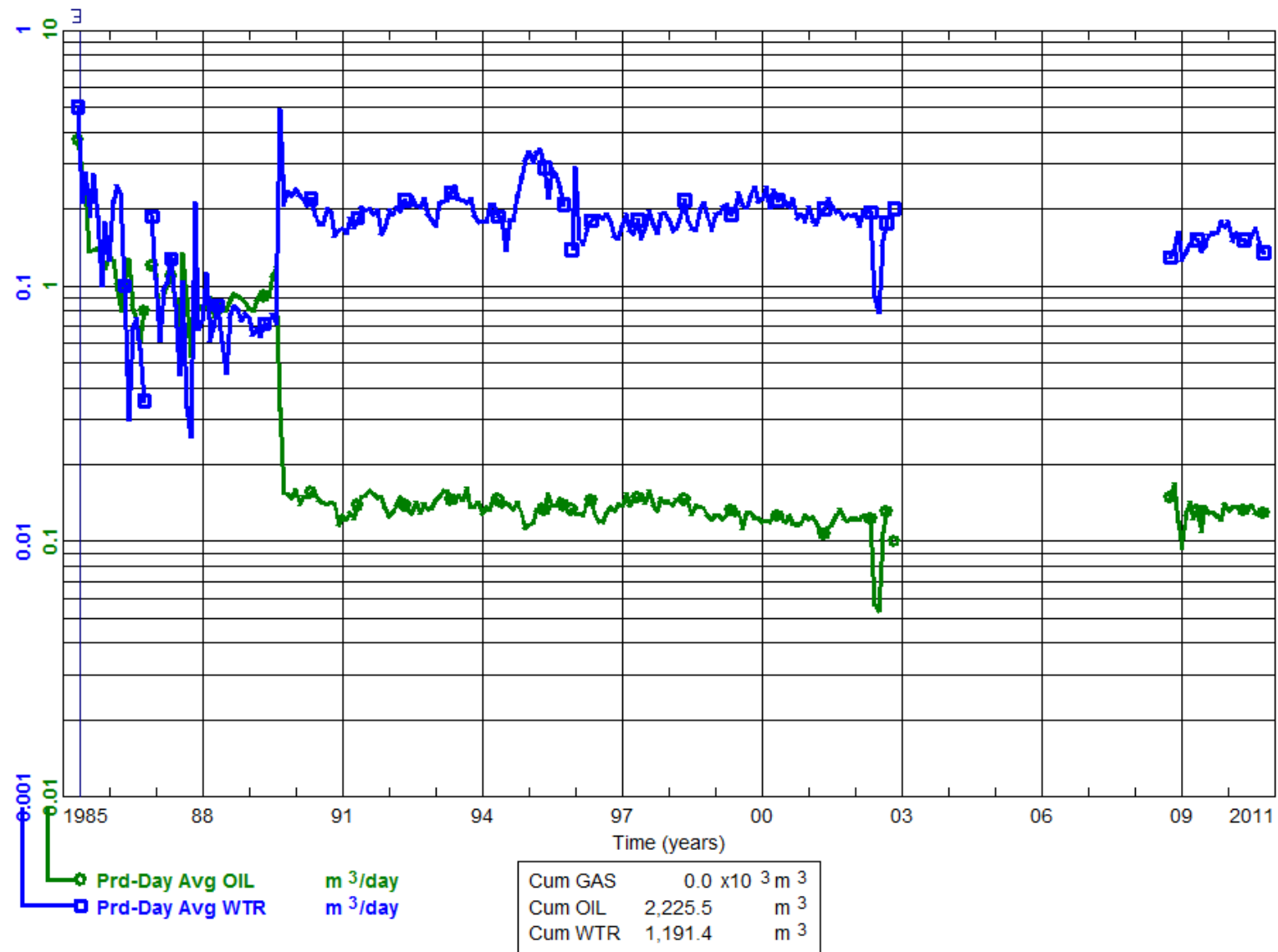
Status: Abandoned Water Inj Well  
Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
From: 1985-05  
To: 2010-10

INDIVIDUAL PRODUCTION  
Waskada Unit No. 8 COM  
100/08-08-002-25W1/02

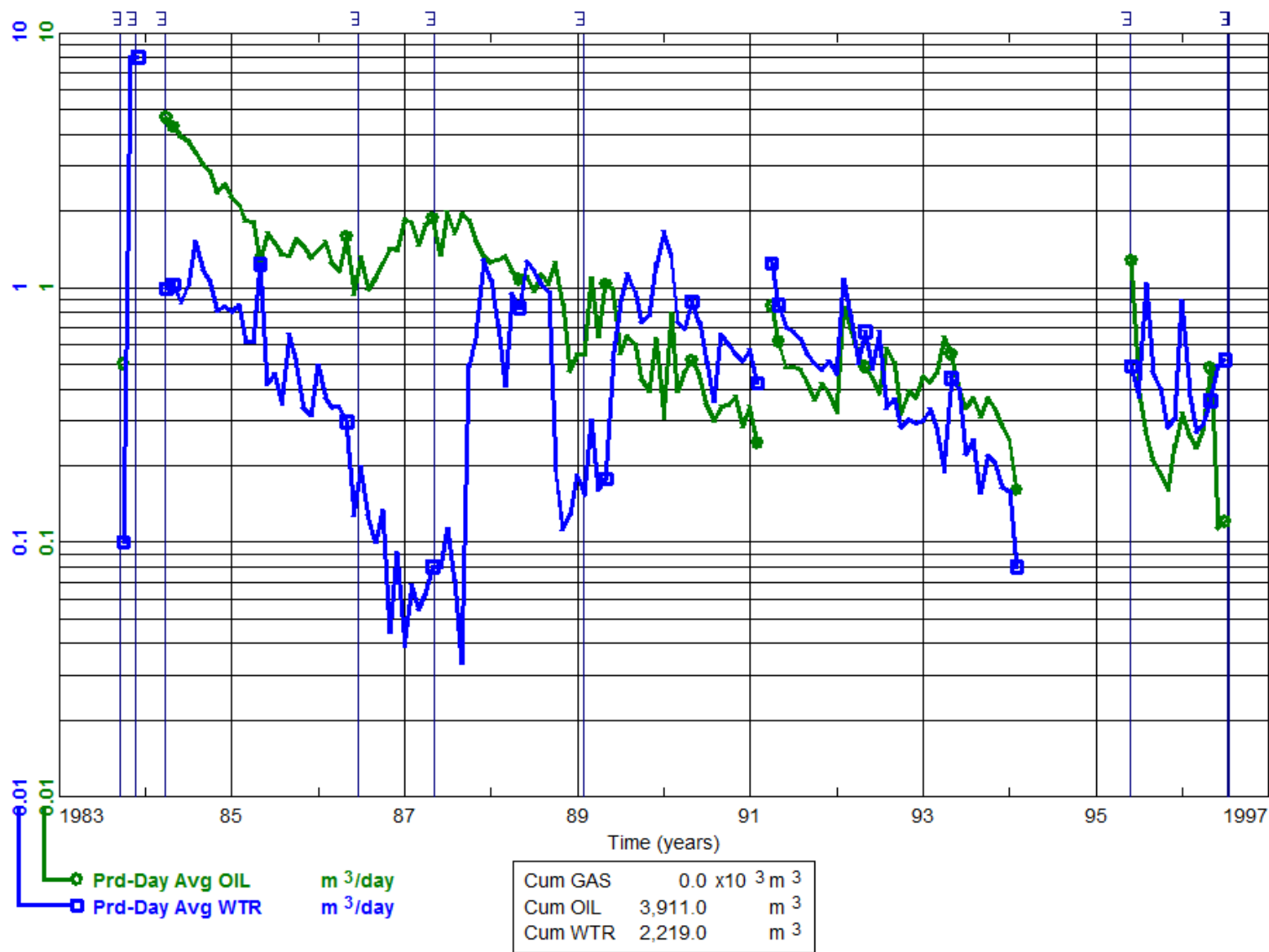
Status: Comingled  
Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1983-10  
 To: 1996-07

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/09-08-002-25W1/00

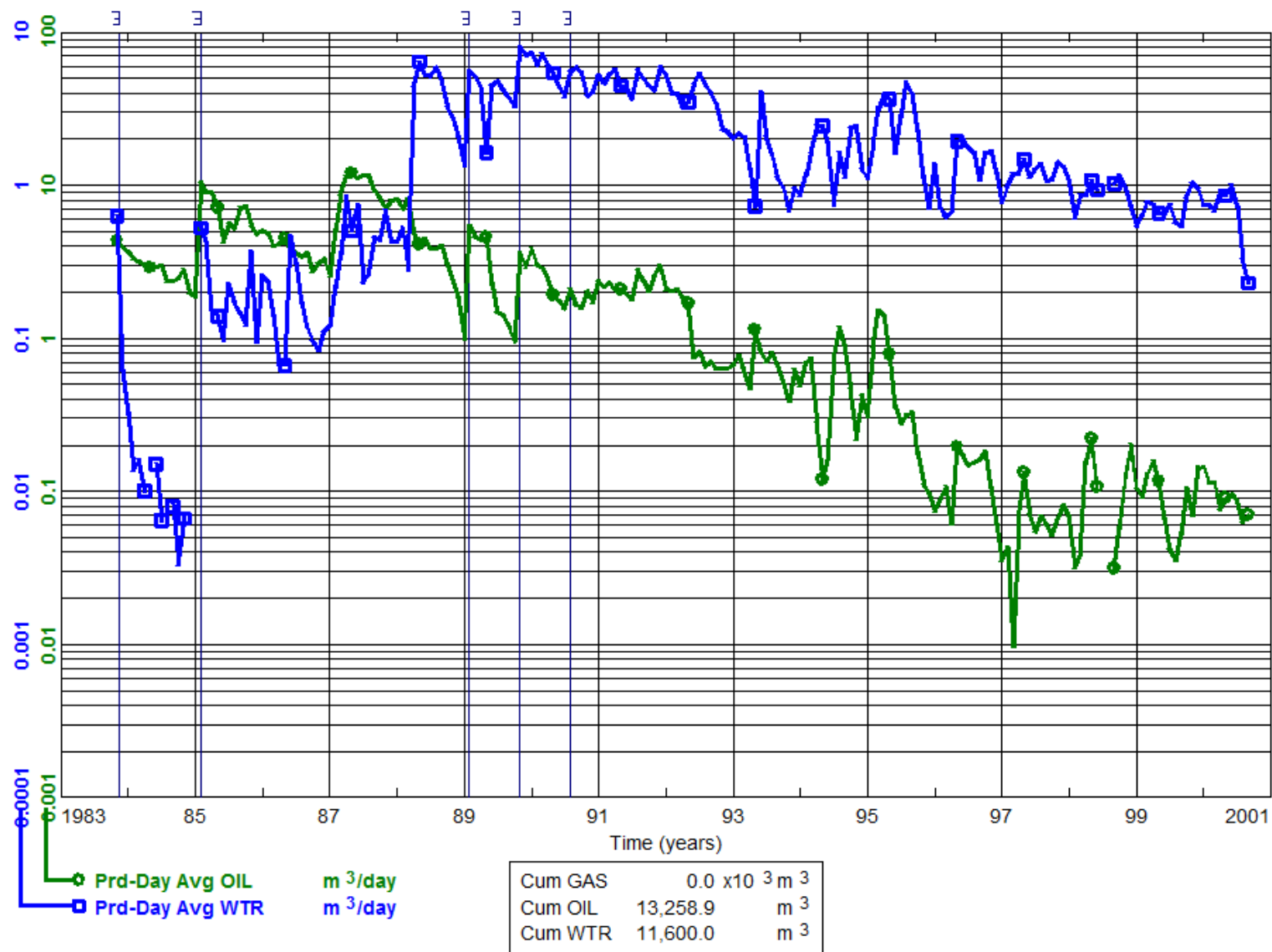
Status: Abandoned Producer  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1983-11  
 To: 2000-09

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/10-08-002-25W1/00

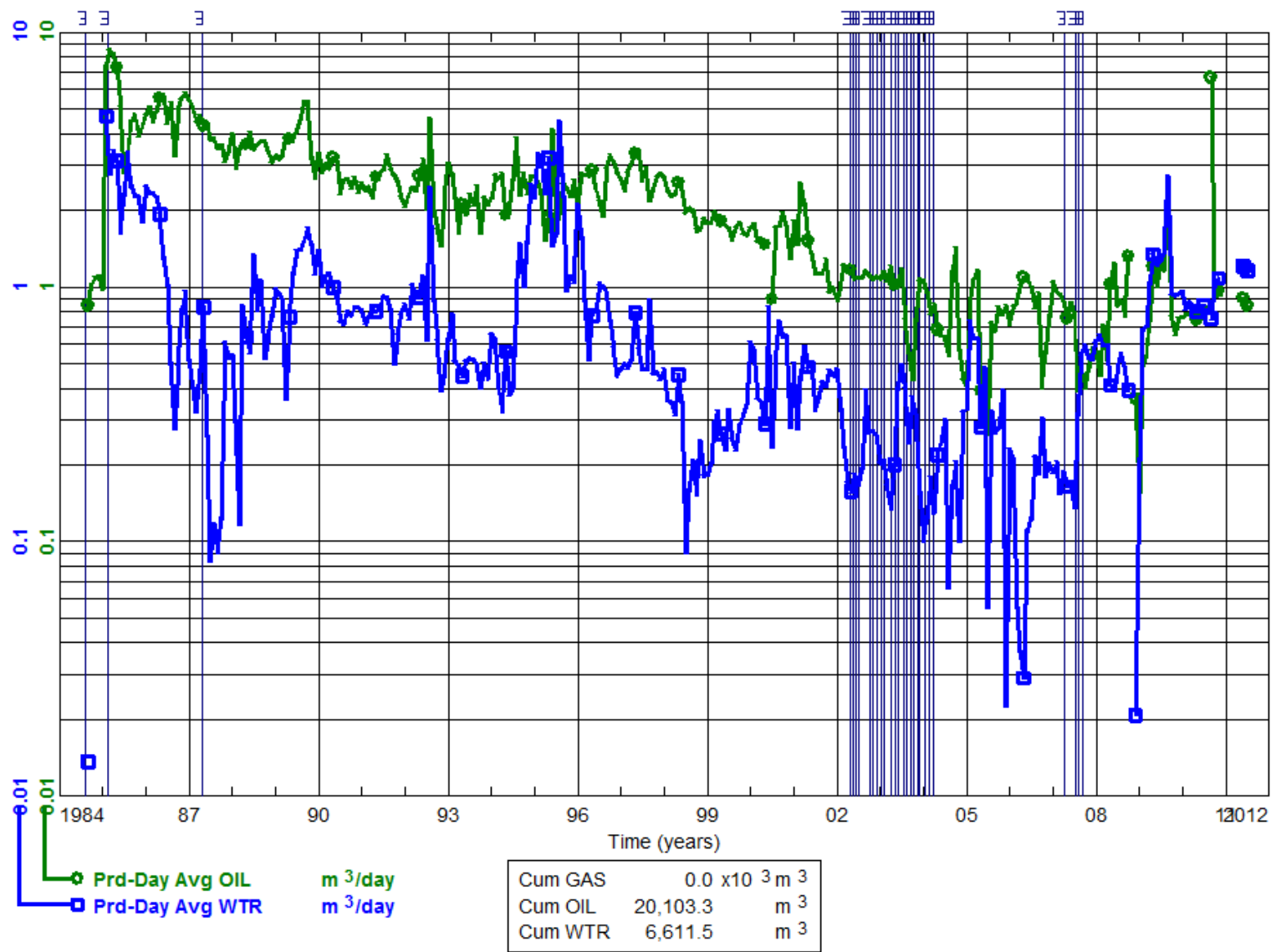
Status: Abandoned Producer  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-09  
 To: 2011-07

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/11-08-002-25W1/00

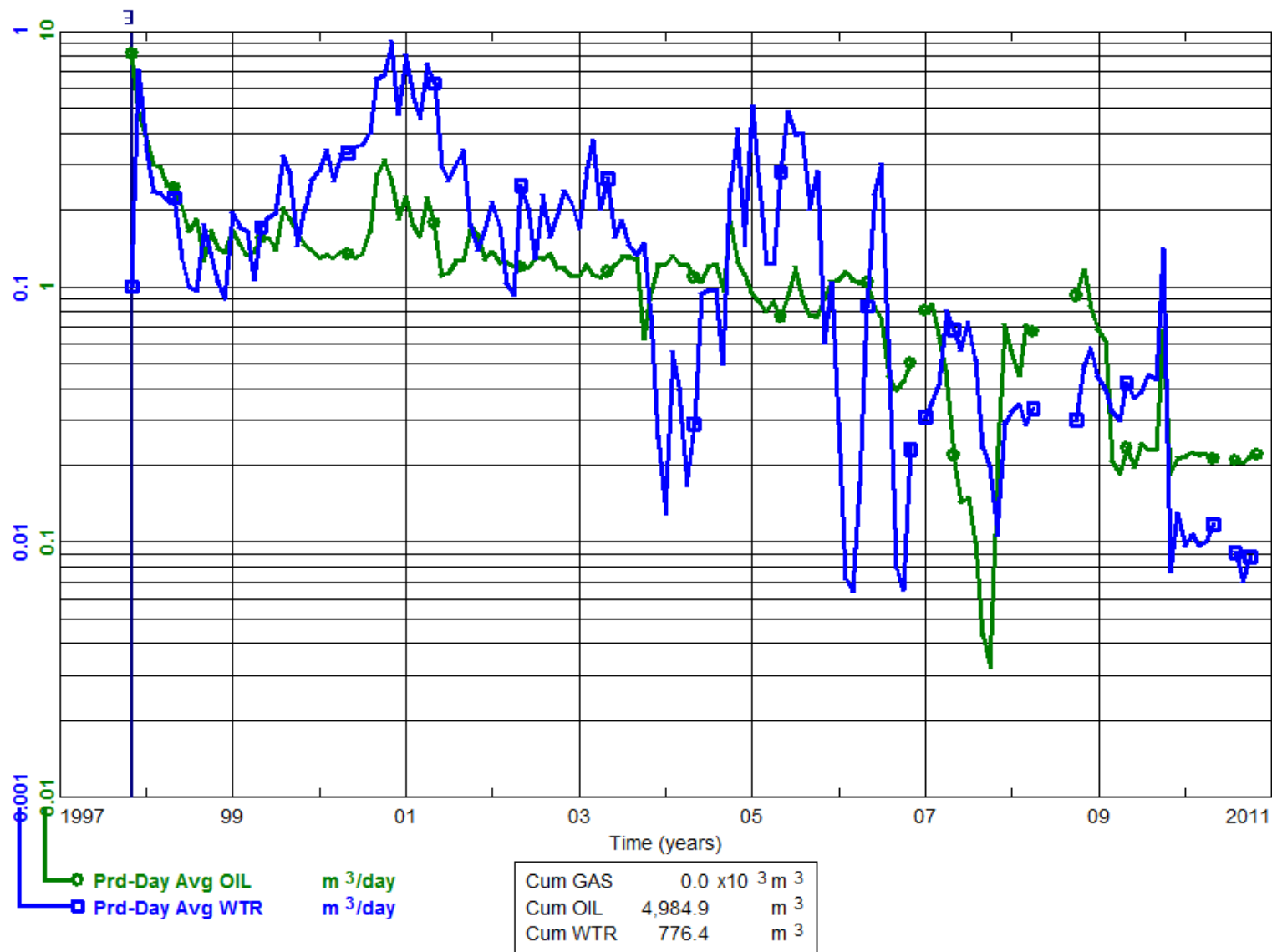
Status: Capable Of Oil Prod  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1997-11  
 To: 2010-11

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 1A0/11-08-002-25W1/00

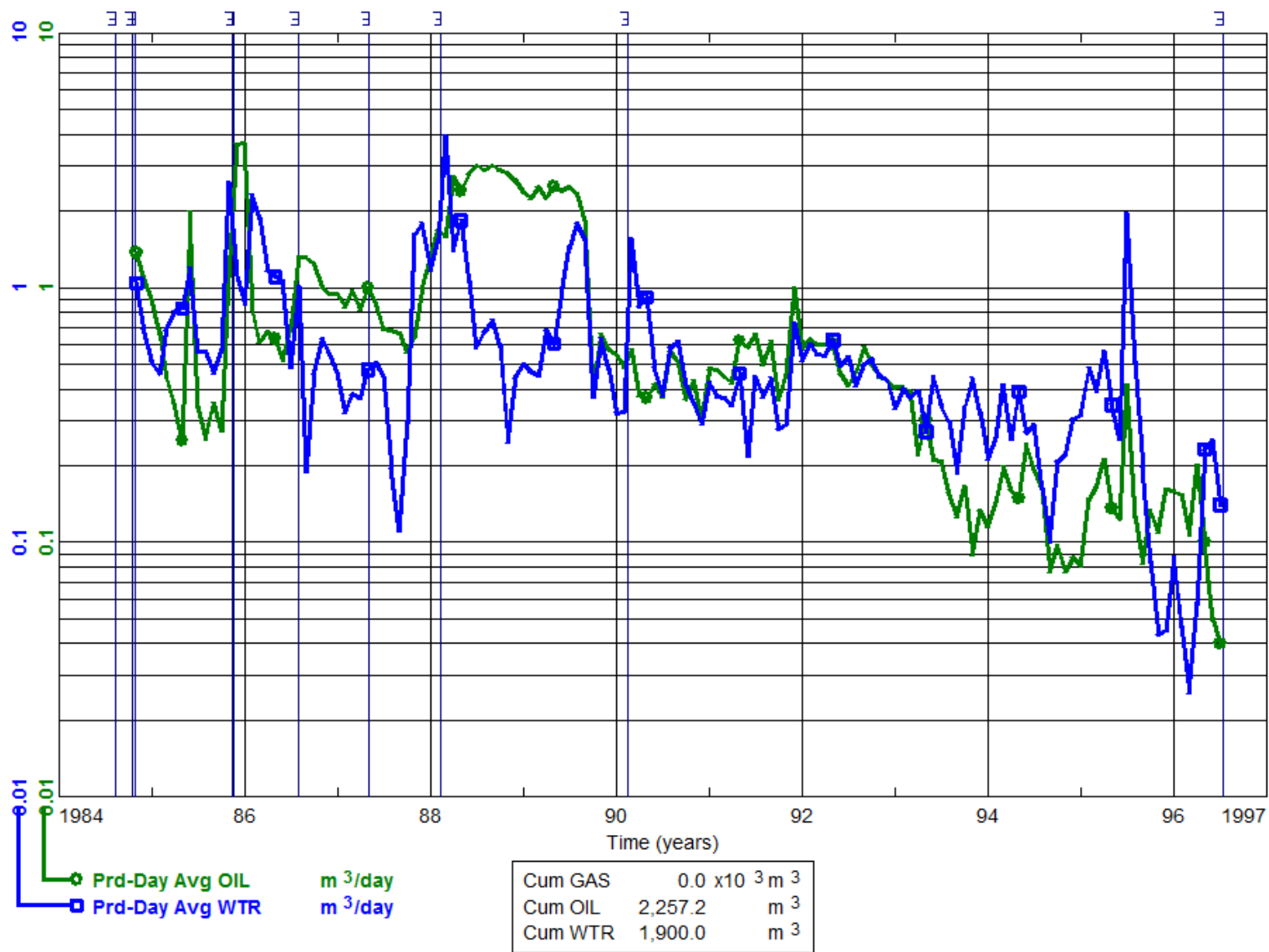
Status: Capable Of Oil Prod  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-11  
 To: 1996-07

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/12-08-002-25W1/00

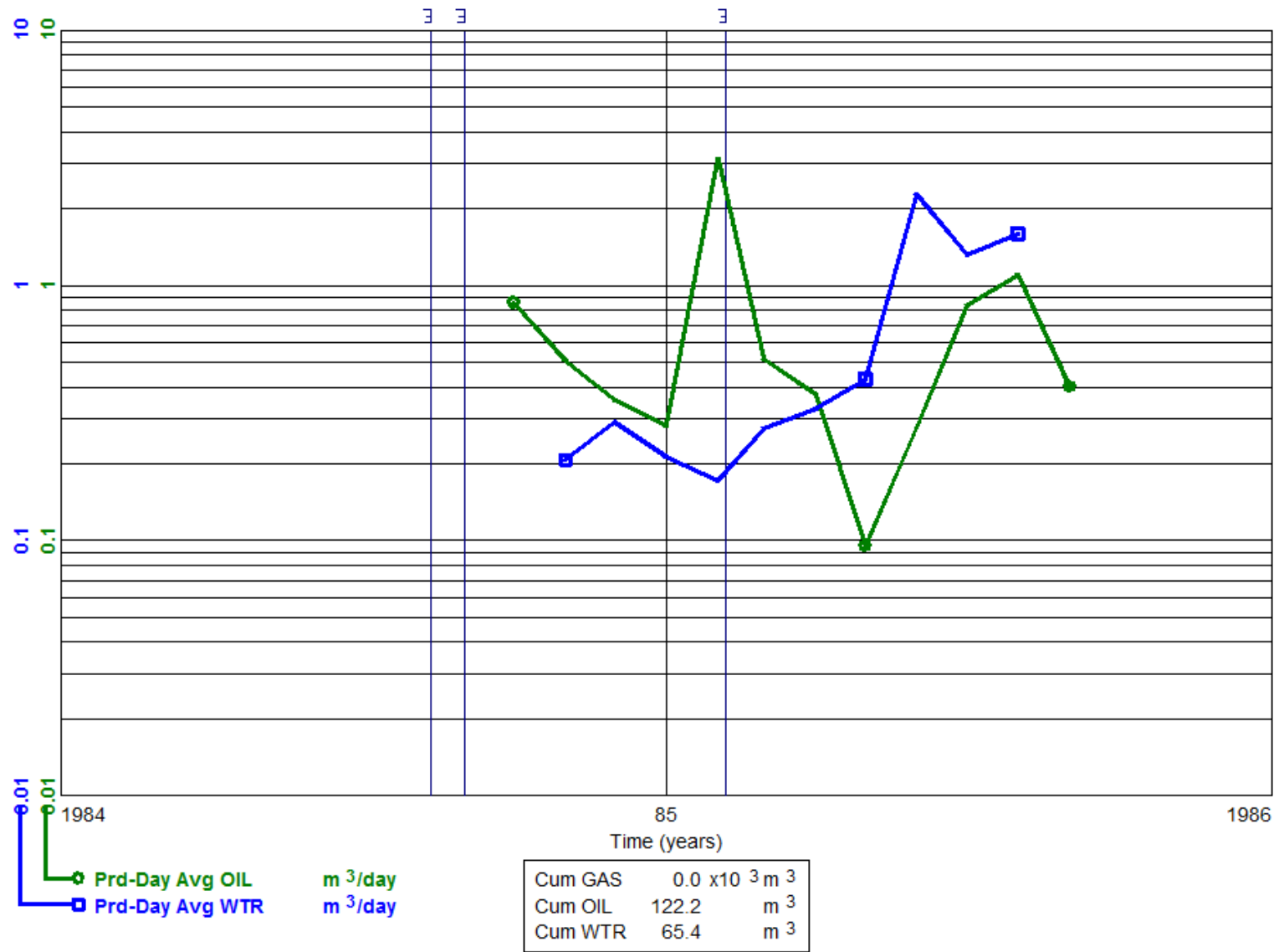
Status: Abandoned Producer  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-10  
 To: 1985-09

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8 WIW  
 100/13-08-002-25W1/00

Status: Water Inj Well  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)

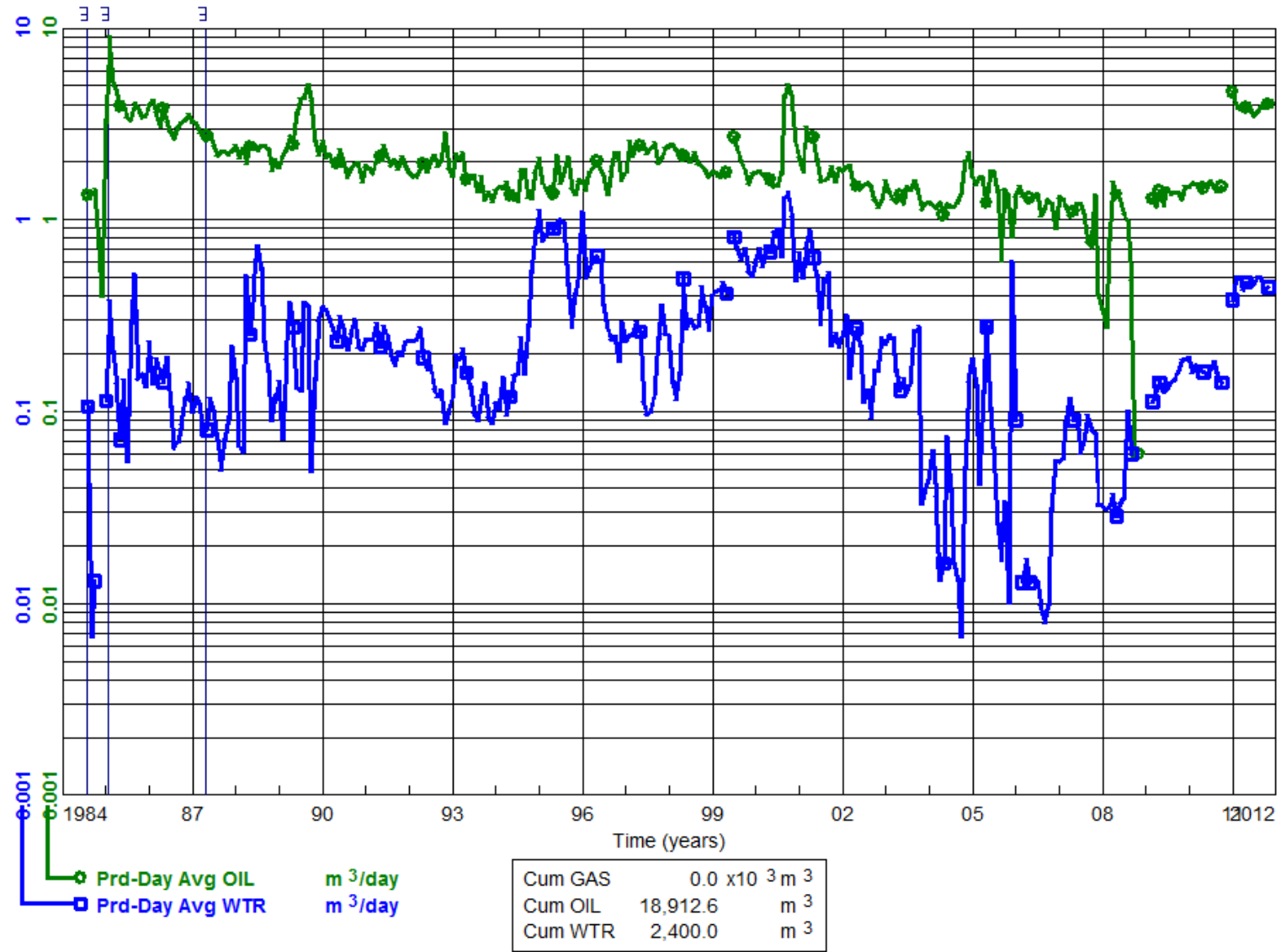




Data As Of: 2011-11 (MB)  
From: 1984-08  
To: 2011-11

INDIVIDUAL PRODUCTION  
Waskada Unit No. 8  
100/14-08-002-25W1/00

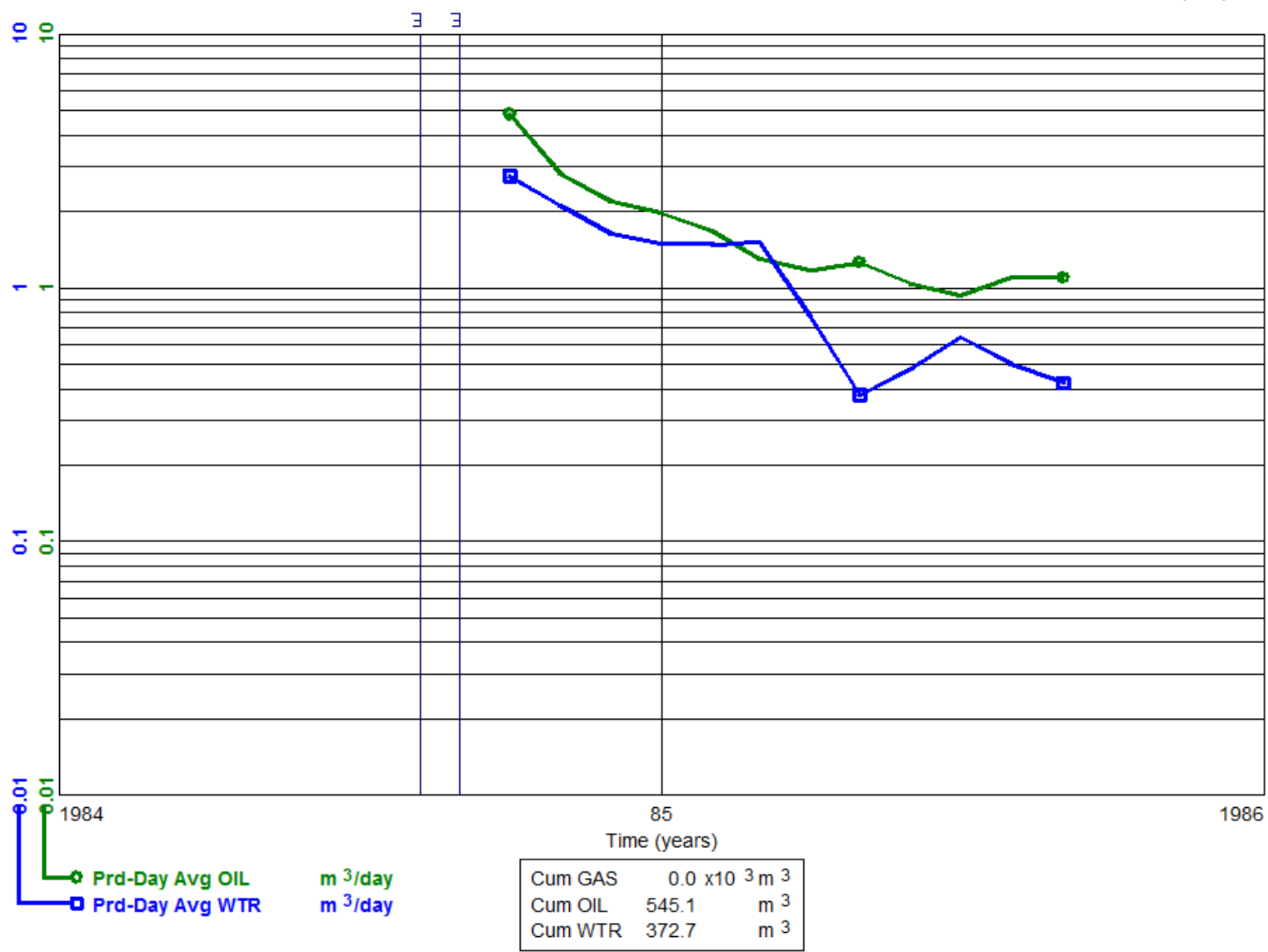
Status: Capable Of Oil Prod  
Field: WASKADA (03)  
Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-10  
 To: 1985-09

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8 WIW  
 100/15-08-002-25W1/00

Status: Water Inj Well  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)



Data As Of: 2011-11 (MB)  
 From: 1984-07  
 To: 2011-03

INDIVIDUAL PRODUCTION  
 Waskada Unit No. 8  
 100/16-08-002-25W1/00

Status: Capable Of Oil Prod  
 Field: WASKADA (03)  
 Pool: LOWER AMARANTH A (29A)

