APPENDIX F
Drawdown Calculations

Drawdown Calculation Narrative

The predicted drawdown in each coal seam was calculated using regional aquifer characteristics. It is assumed that confined aquifer calculations will adequately address the drawdown in these aquifers since the clay rich layers in the Tongue River member of the Fort Union formation are known to make the vertical hydraulic conductivity of this unit very low. These calculations also assume isotropy and homogeneity of the coal seam aquifers. Based upon the results of 370 aquifer tests Wheaton and Metesh (2002) have calculated that the geometric mean horizontal hydraulic conductivity value of the coal seam aquifers in the Fort Union Formation is 1.1 feet per day. The geometric mean horizontal hydrologic conductivity less one standards deviation is $9.8x10^{-2}$ feet per day, and the horizontal hydrologic conductivity plus one standards deviation is 13 feet per day. Mean storativity values of these coals are approximately $9x10^{-4}$ (storativity is unitless) (Wheaton and Metesh, 2002). The average thickness of the produced coal seams from the Well prognoses contained in the POD Book is as follows: Dietz 1 = 25 feet; Dietz 2 = 19 feet; Dietz 3 = 17 feet; Monarch = 22 feet; Carney = 23 feet. A total of 178 CBNG wells would be finished in these 5 coal seams.

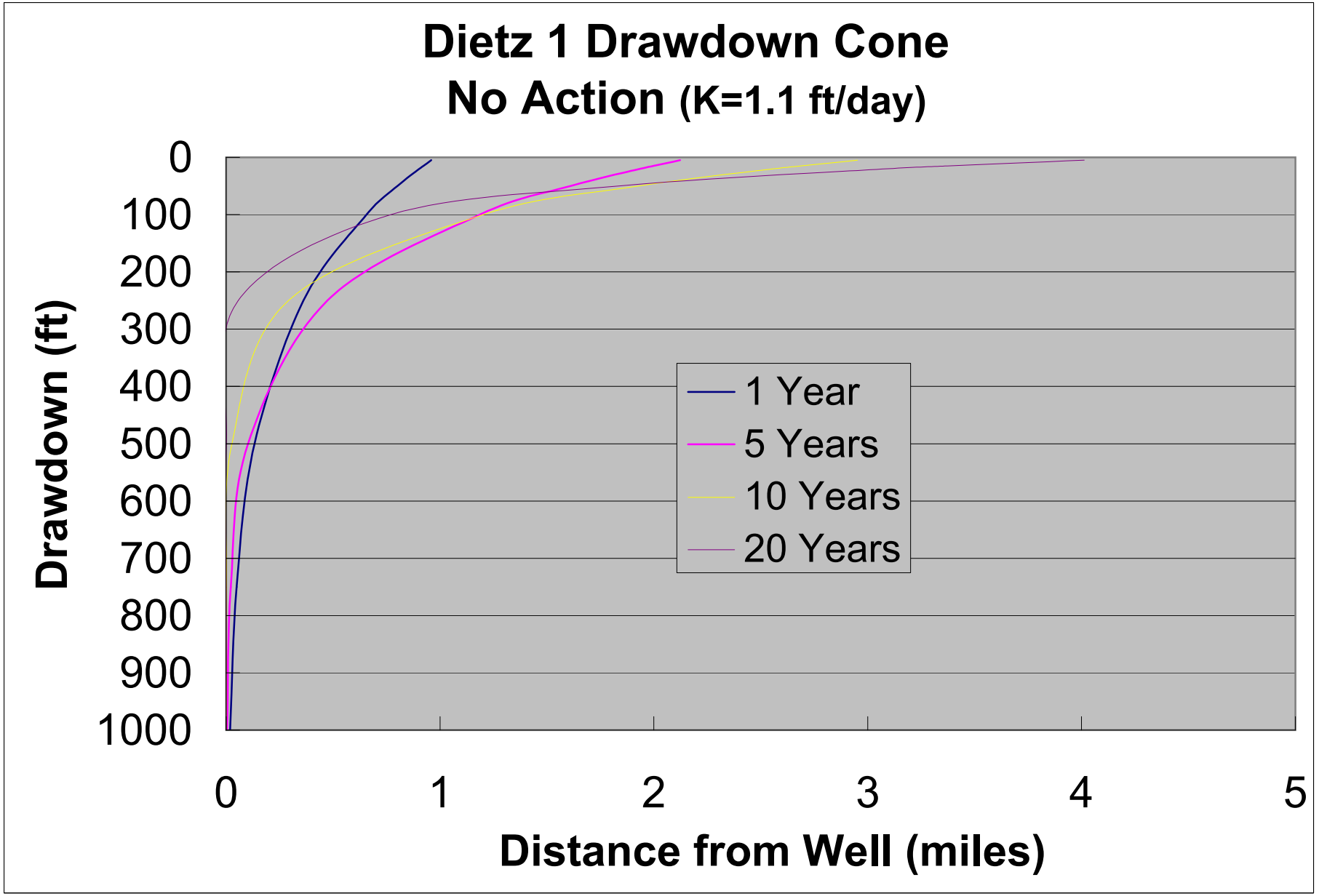
Using this method the distance that a variety of drawdown values extend from the edge of the produced field was estimated by assuming that all wells finished in each coal seam can be approximated by one well that produces water at the same rate that all wells finished in that seam would produce, on average, over the period of time being analyzed. For this analysis the distance that the 20 foot drawdown contours would extend from the pumped CBNG well was of particular concern. These values were determined for each of the 5 coal seams for 1 year, 5 years, 10 years, and 20 years from the start of production, and calculated for horizontal hydrologic conductivity values of $9.8x10^{-2}$, 1.1, and 13 feet per day. The results of this analysis for the hydrologic conductivity of 1.1 feet/day are shown in the table below. Charts of the drawdown cones are also included. The radius of the 5 foot drawdown contour was also calculated and is shown on the table below.

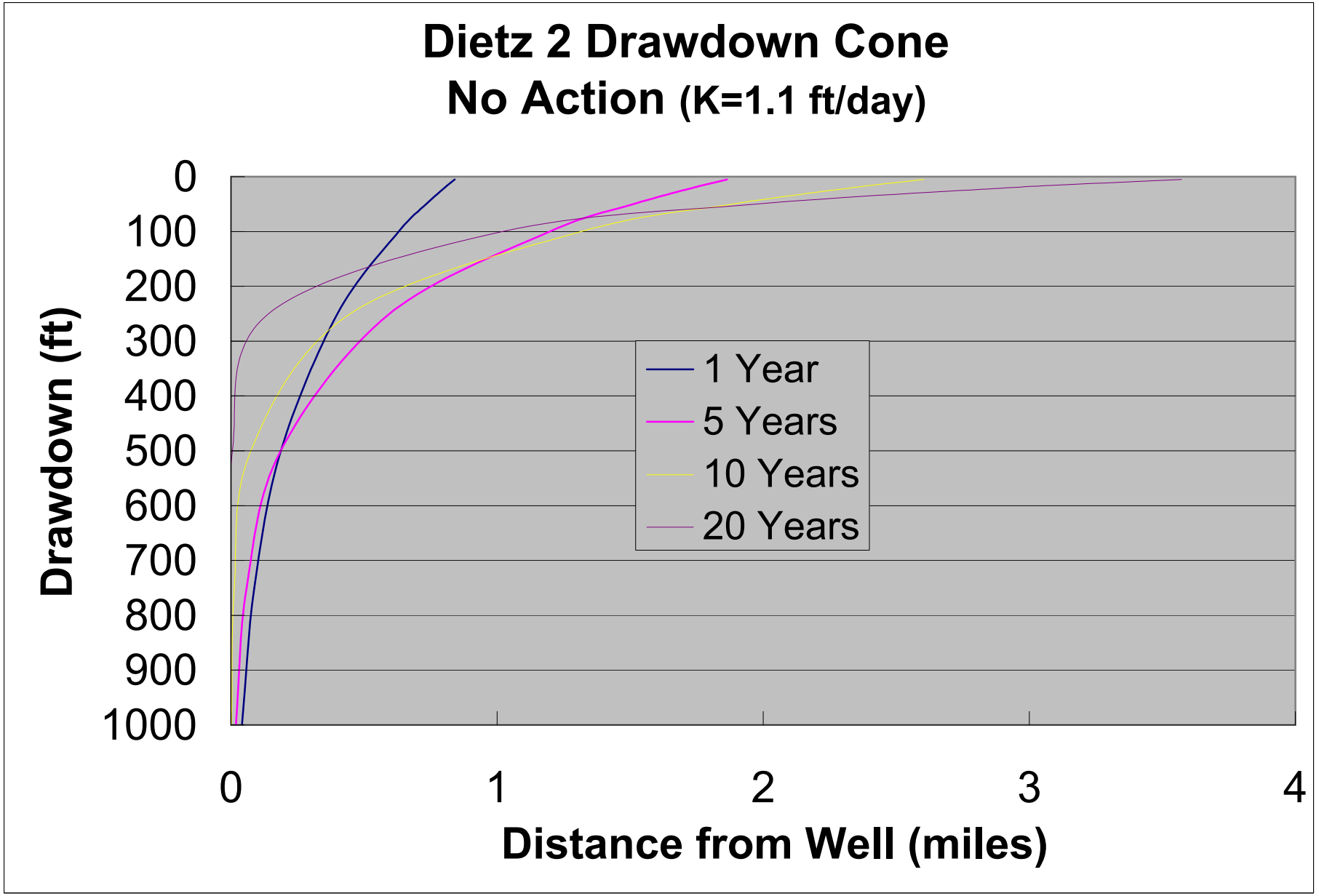
Using the geometric mean horizontal hydraulic conductivity value (1.1 feet/day) the 20 foot drawdown contour may extend up to 3.6 miles from the produced field after 20 years. These results are similar to the results of the 3D groundwater model prepared in support of the MT-CBM-EIS, which modeled 1,082 CBNG wells and indicated that the 20 foot drawdown contour may extend up to 5 miles from the edge of production (Wheaton and Metesh, 2002).

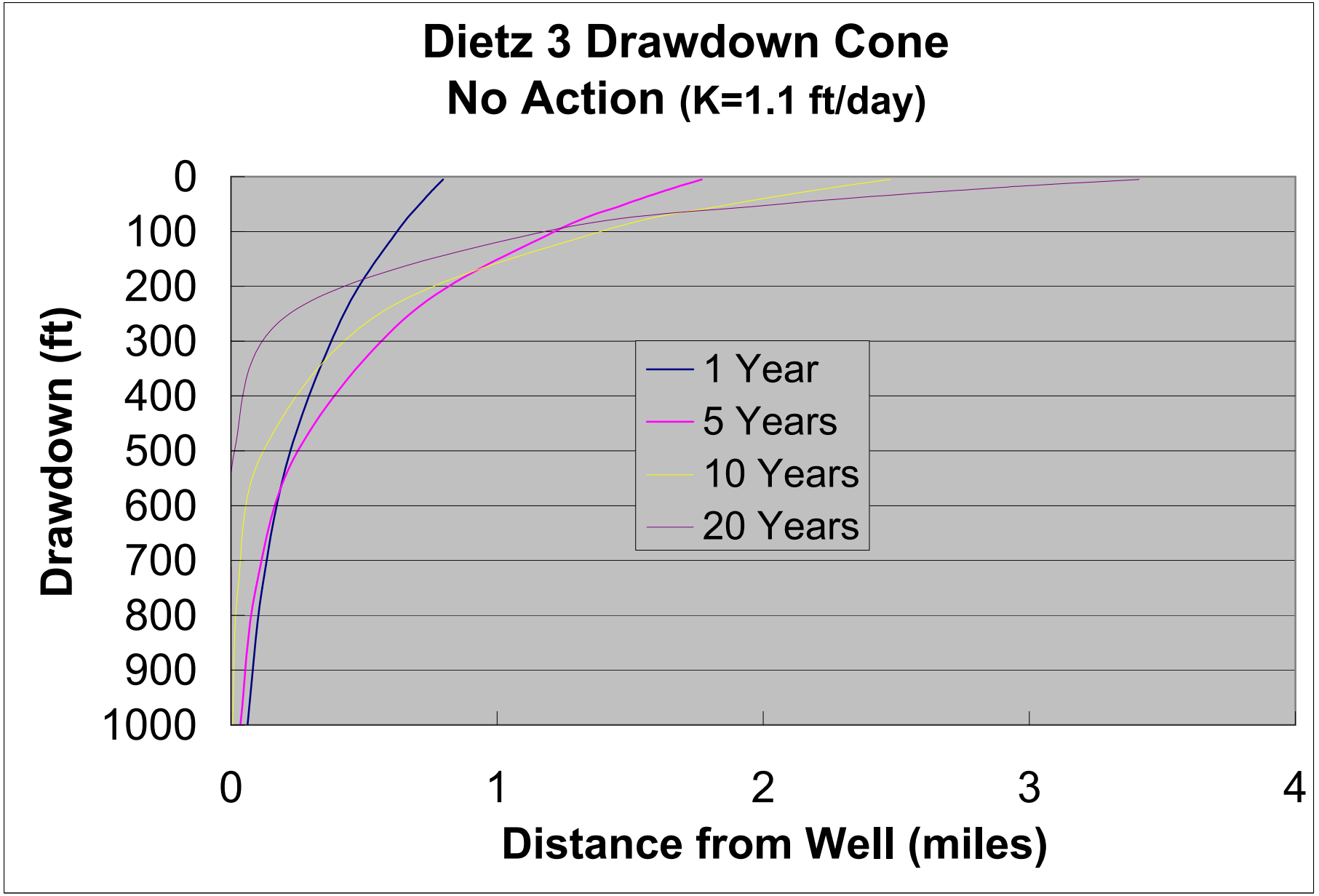
Summary of Predicted Drawdown from the Badger Hills CBNG Project

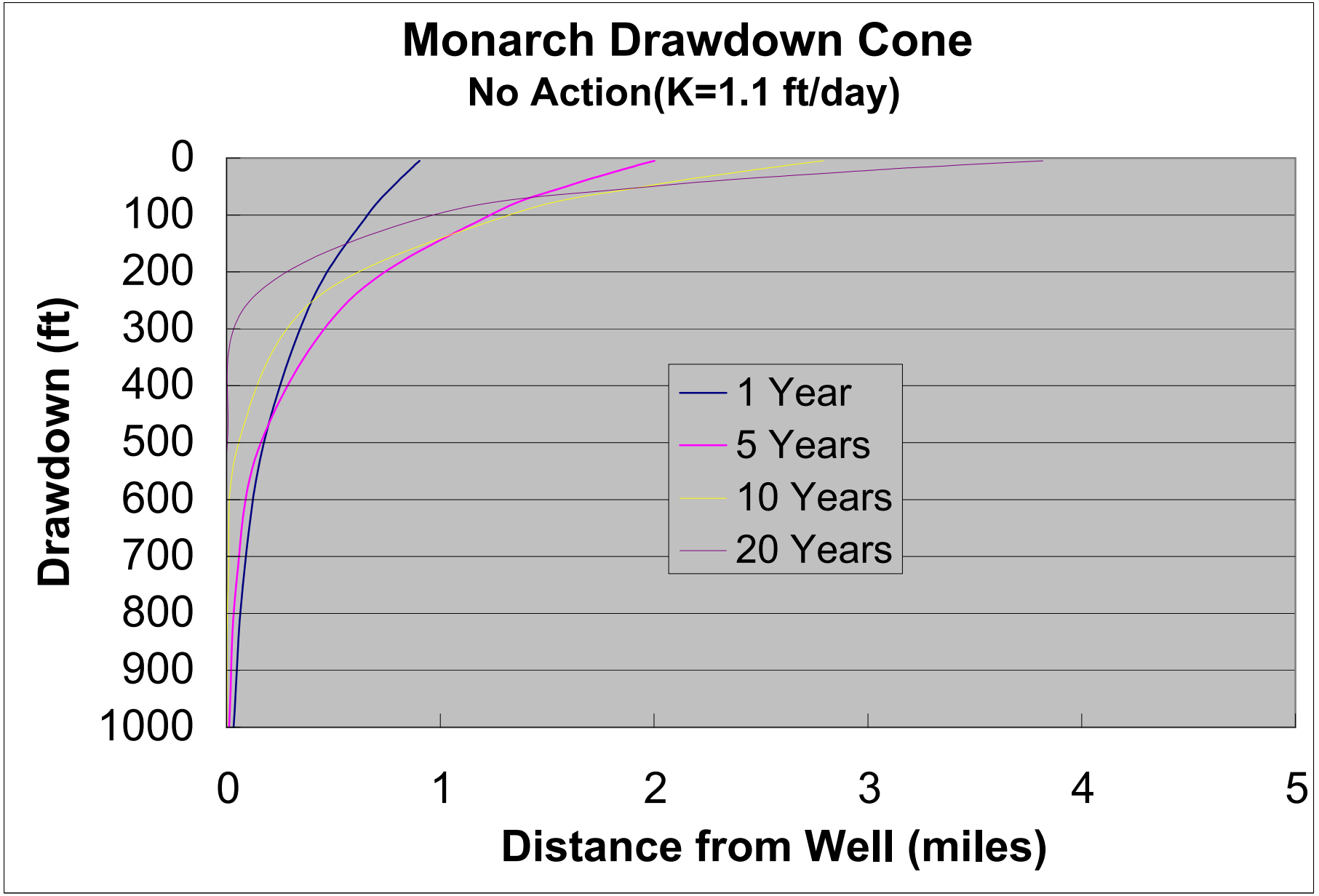
Years Pumped	Average Pumping Rate (gpm)	Coal Seam	State and Fee Wells per Seam	Federal Wells per Seam	Drawdown Radius(miles)				Difference (miles)	
					No Action		Proposed Action			
					5 foot	20 foot	5 foot	20 foot	5 foot	20 foot
1 Year	12.6	Dietz 1	18	14	0.96	0.90	0.97	0.94	0.01	0.03
		Dietz 2	18	18	0.84	0.80	0.85	0.83	0.01	0.02
		Dietz 3	19	17	0.80	0.77	0.80	0.79	0.00	0.02
		Monarch	19	18	0.90	0.86	0.91	0.89	0.01	0.03
		Carney	19	18	0.92	0.88	0.93	0.91	0.01	0.03
5 Years	8.2	Dietz 1	18	14	2.1	1.9	2.2	2.0	0.03	0.11
		Dietz 2	18	18	1.9	1.7	1.9	1.8	0.02	0.08
		Dietz 3	19	17	1.8	1.7	1.8	1.7	0.02	0.07
		Monarch	19	18	2.0	1.9	2.0	1.9	0.02	0.09
		Carney	19	18	2.0	1.9	2.1	2.0	0.03	0.10
10 Years	5.3	Dietz 1	18	14	3.0	2.6	3.0	2.8	0.06	0.22
		Dietz 2	18	18	2.6	2.3	2.7	2.5	0.05	0.17
		Dietz 3	19	17	2.5	2.3	2.5	2.4	0.04	0.14
		Monarch	19	18	2.8	2.5	2.8	2.7	0.05	0.20
		Carney	19	18	2.8	2.5	2.9	2.7	0.06	0.21
20 Years	2.9	Dietz 1	18	14	4.0	3.1	4.2	3.6	0.16	0.51
		Dietz 2	18	18	3.6	2.9	3.7	3.3	0.12	0.41
		Dietz 3	19	17	3.4	2.9	3.5	3.2	0.09	0.33
		Monarch	19	18	3.8	3.1	4.0	3.5	0.14	0.47
		Carney	19	18	3.9	3.1	4.0	3.6	0.15	0.49

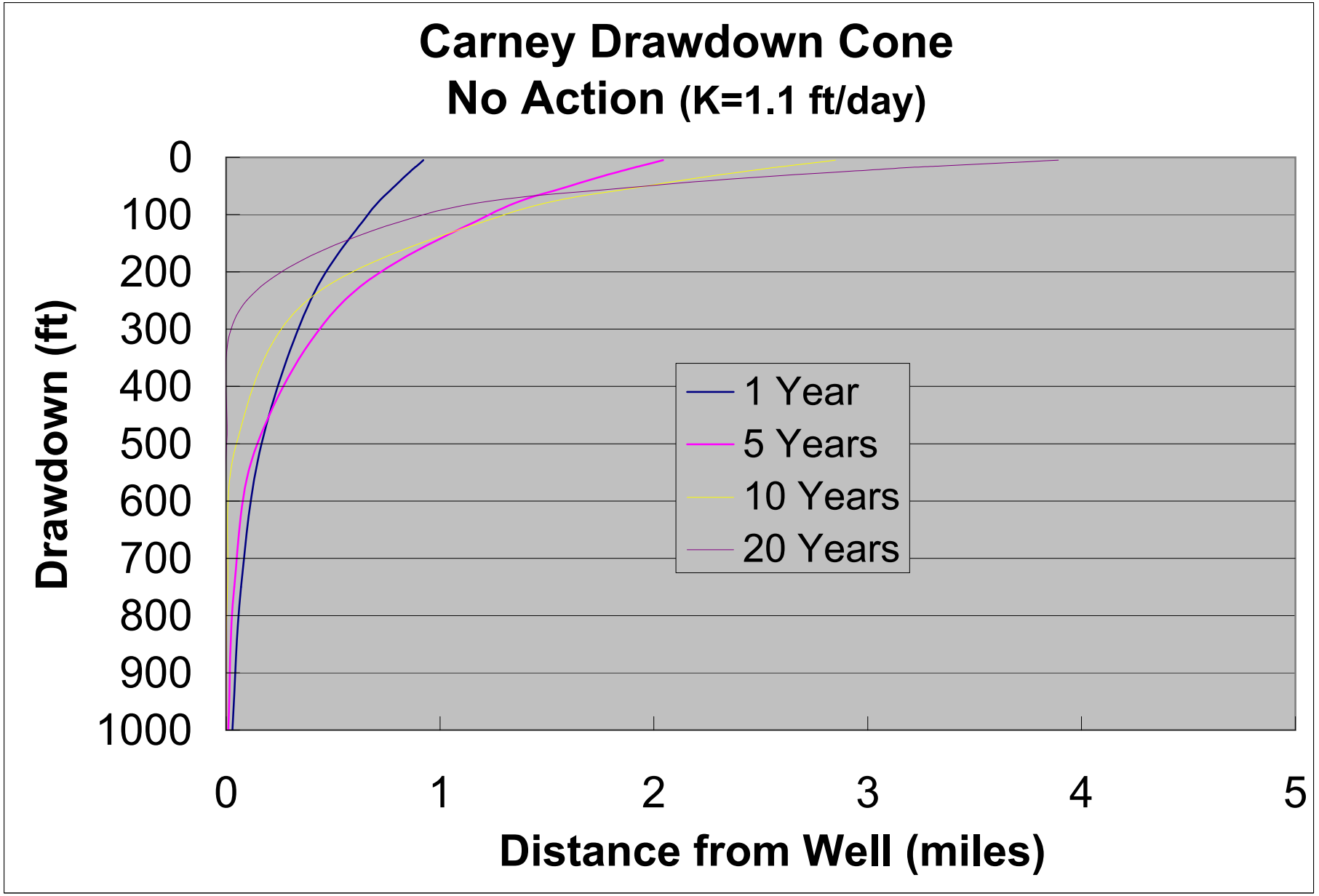
K = 1.1 feet/day S = 9×10^{-4}

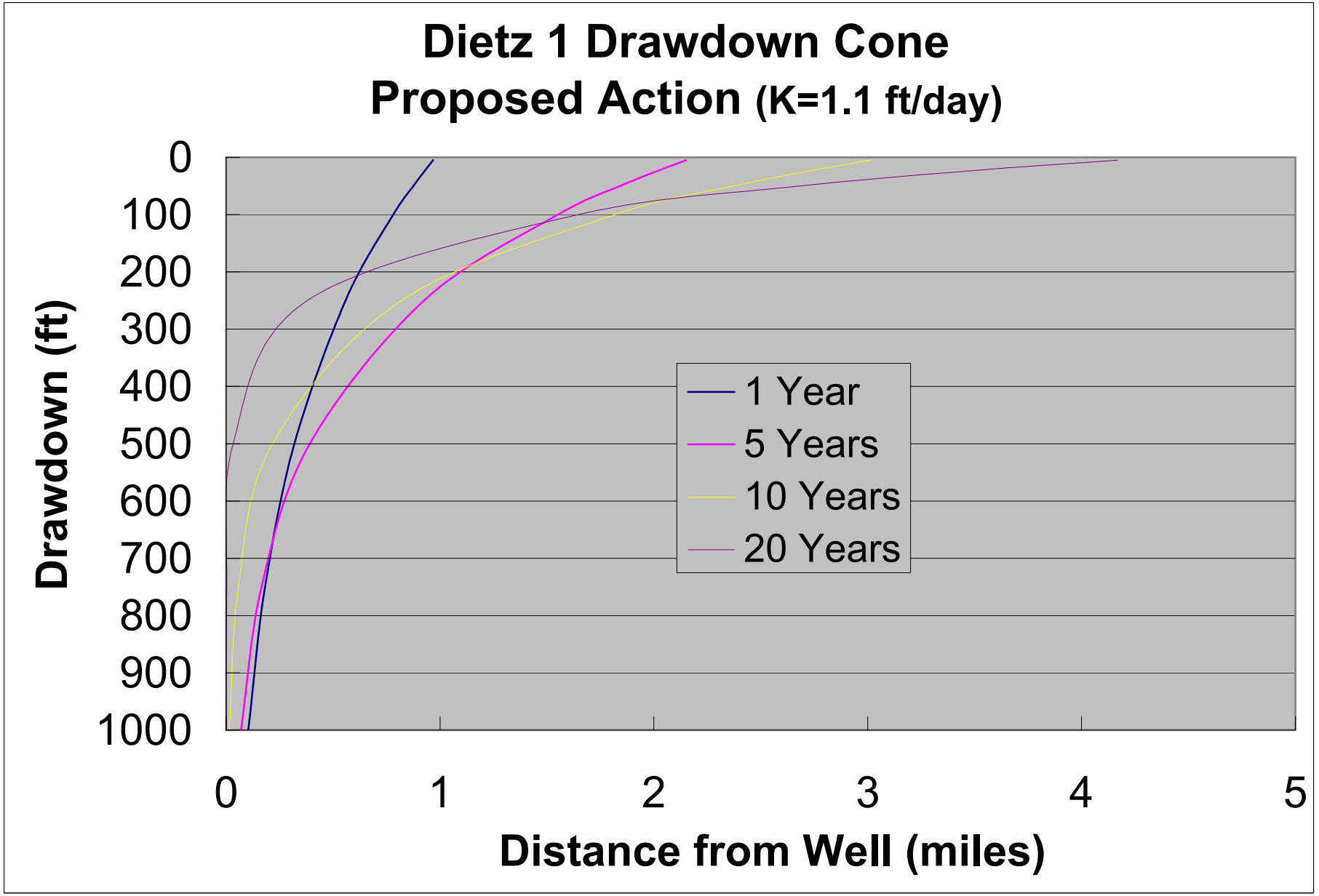

Dietz 1 Drawdown Cone
No Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
5
Distance from Well (miles)

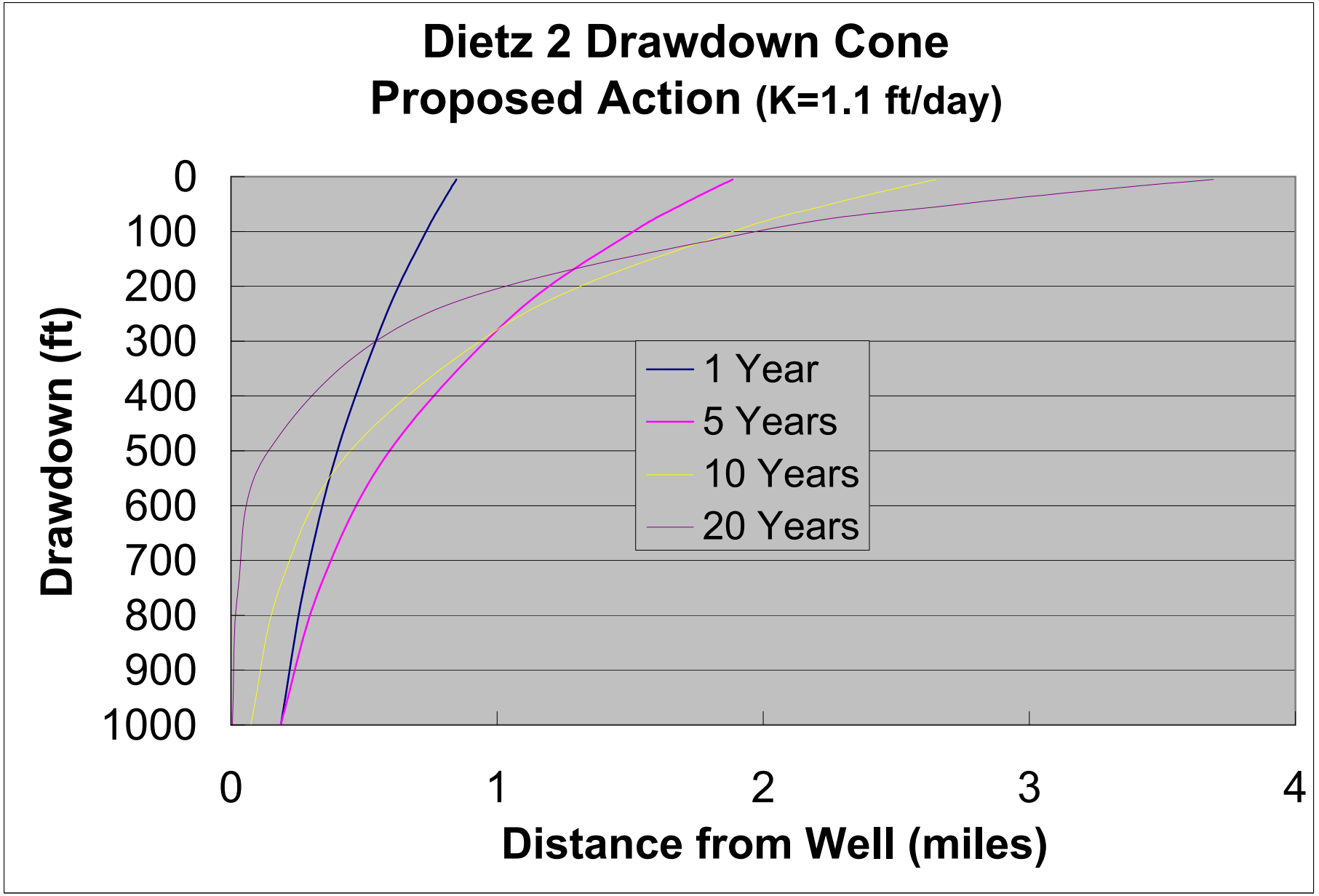

Dietz 2 Drawdown Cone
No Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
Distance from Well (miles)

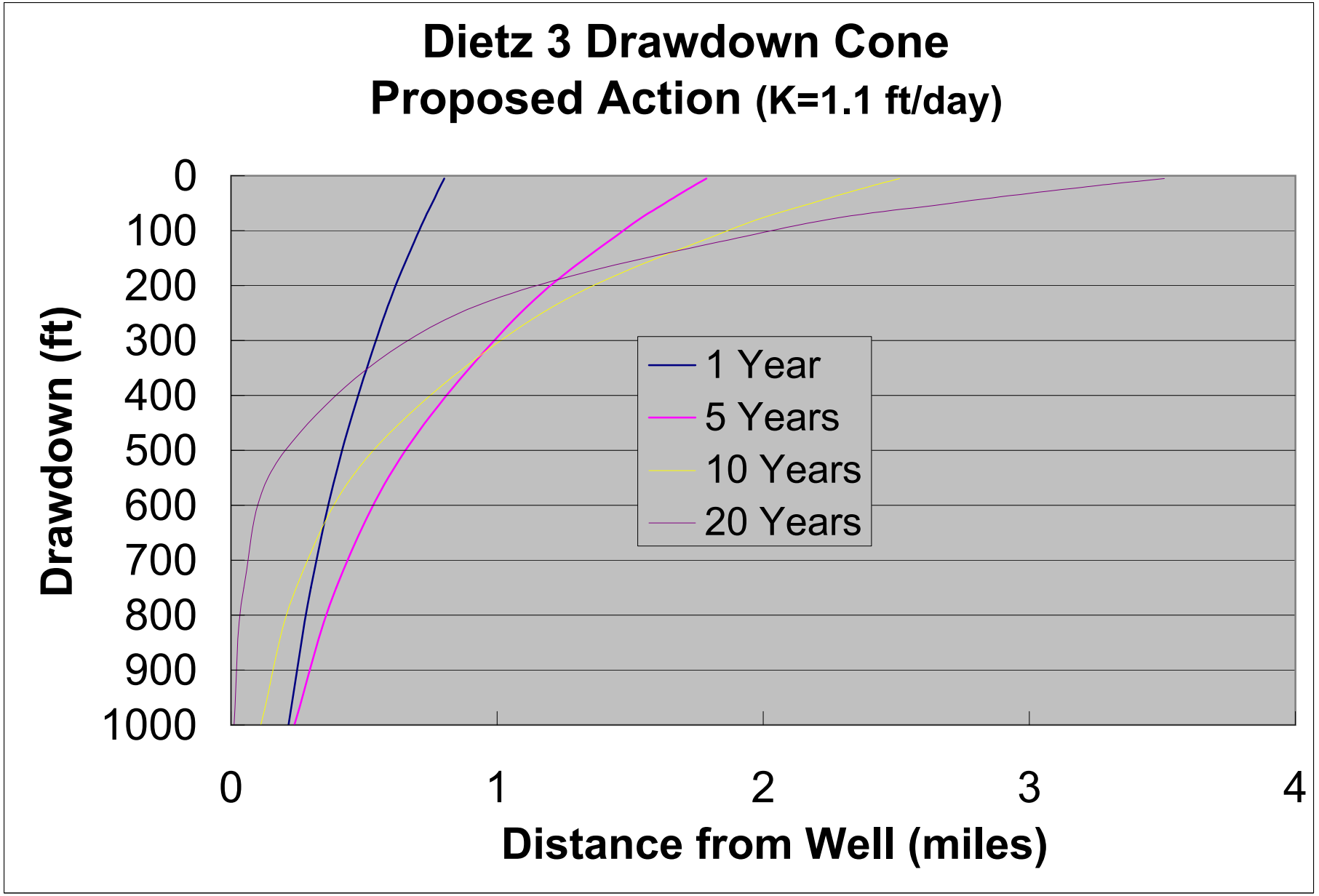

Dietz 3 Drawdown Cone
No Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
Distance from Well (miles)

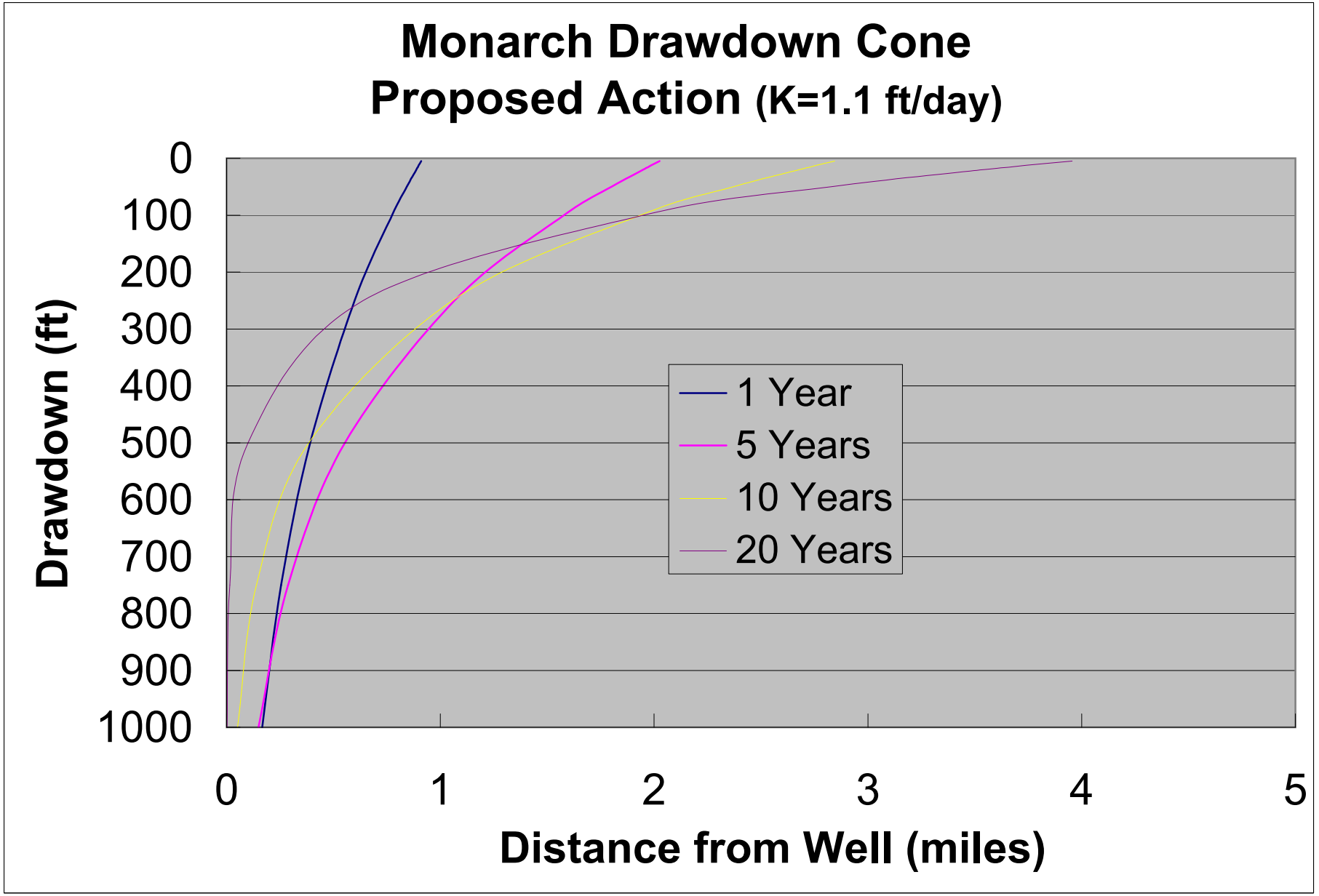

Monarch Drawdown Cone
No Action(K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
5
Distance from Well (miles)

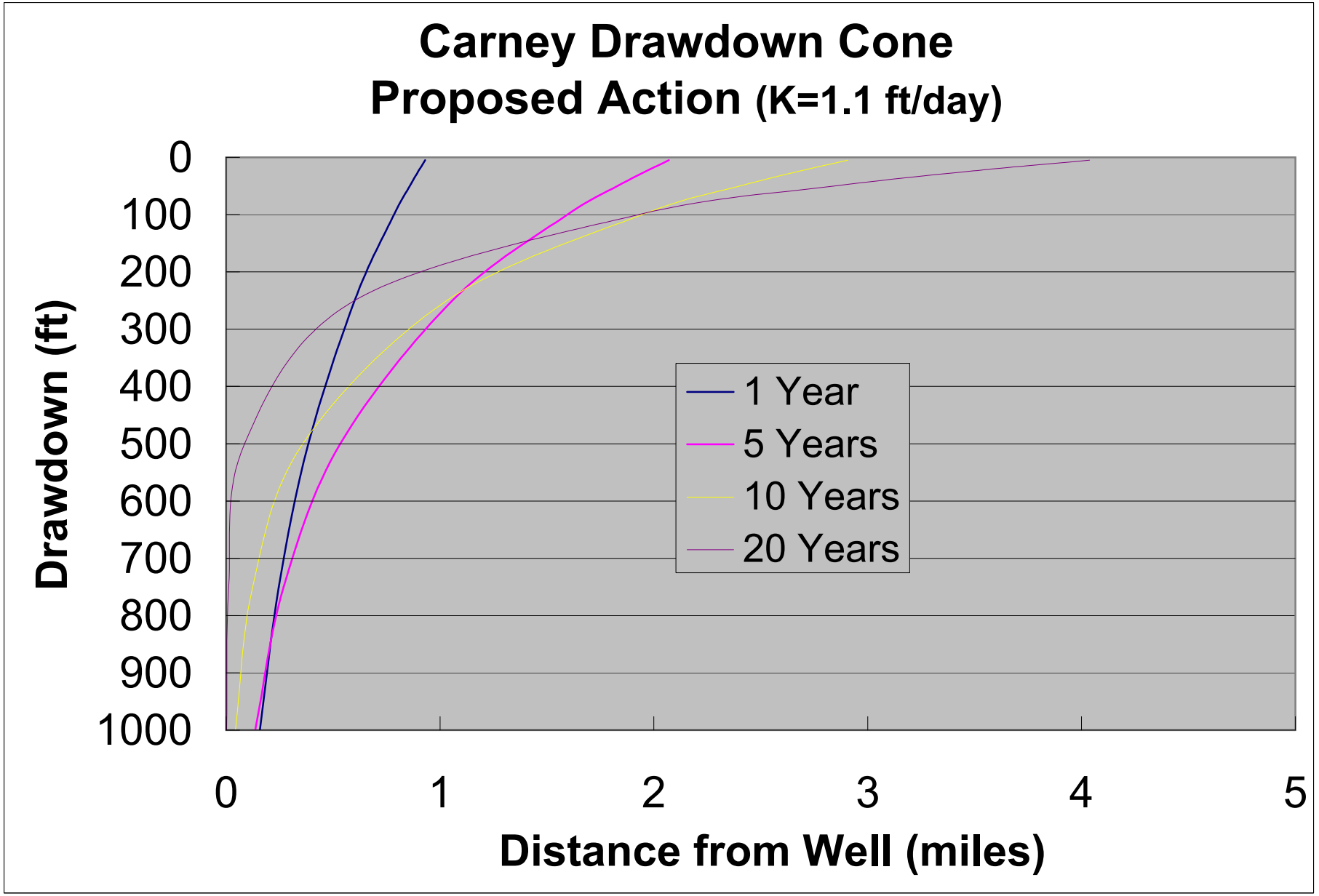

Carney Drawdown Cone
No Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
5
Distance from Well (miles)


Dietz 1 Drawdown Cone
Proposed Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
5
Distance from Well (miles)


Dietz 2 Drawdown Cone
Proposed Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
Distance from Well (miles)


Dietz 3 Drawdown Cone
Proposed Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
Distance from Well (miles)


Monarch Drawdown Cone
Proposed Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
5
Distance from Well (miles)


Carney Drawdown Cone
Proposed Action (K=1.1 ft/day)
Drawdown (ft)
0
100
200
300
400
500
600
700
800
900
1000
1 Year
5 Years
10 Years
20 Years
0
1
2
3
4
5
Distance from Well (miles)

1 Year; Dietz 1; K=1.1

dh (Feet)	1000	750	500	250	100	50	20	15	10	5	0.1
Q	401.6864	gpm	77330	ft3/day							
K	1.10E+00	ft/day									
h	25	ft									
T	28	ft2/day									
S	9.00E-04	unitless									
t	365	days									
W(u)	4.469	3.352	2.234	1.117	0.447	0.223	0.089	0.067	0.045	0.022	0.000
			u=0.5986*EXP(-1.0042*W(u))								
u	6.73E-03	2.07E-02	6.35E-02	1.95E-01	3.82E-01	4.78E-01	5.47E-01	5.60E-01	5.72E-01	5.85E-01	5.98E-01
r (feet)	548	960	1683	2949	4129	4619	4941	4997	5053	5110	5166
r (miles)	0.10	0.18	0.32	0.56	0.78	0.87	0.94	0.95	0.96	0.97	0.98

input
calculation
result

miles	feet	dh
0.10379695	548	1000
0.18188732	960	750
0.31872804	1683	500
0.55851921	2949	250
0.78200372	4129	100
0.87484756	4619	50
0.93576442	4941	20
0.94632188	4997	15
0.95699846	5053	10
0.9677955	5110	5