

# Diffusivity Calculations

Calculated pressure Rise vs. Distance (Diffusivity Equation) - Minnelusa Formation Table A-3 Class V Permit App

$dp = -70.6[(qBu)/(kh)][\ln(1688.388*por*u*ct*rw^2/kt) - 2s]$   
 dp= pressure differential  
 q= flowrate (STB/d)  
 B= formation volume factor (RB/STB)  
 u= viscosity (cp)  
 k= permeability (md)  
 h= reservoir thickness (feet)  
 por= formation effective porosity (percent)  
 ct= total matrix and fluid compressibility (1/psi)  
 rw= radius (feet)  
 t= injection time (hours)  
 s= skin factor (units)

where  
 solve psi  
 2,571.43 bbl/d  
 1.01 RB/STB  
 0.74 cp  
 150 md  
 164 feet  
 0.21 fraction  
 6.50E-06 psi<sup>-1</sup>  
 variable feet  
 87600  
 0  
 10 years

Term 1=  $-70.6(qBu/kh)$   
 Term 2=  $(por*u*ct*rw^2/kt)$   
 dp= Term 1 \*  $\ln(1688.388*Term2)$

Injection Rate (gpm)= 75

Radius (rw) (ft)	Term 1	Term 2	$[\ln(1688.388*Term 2) - 2s]$	dp (psi)	
0.26042	-5.51566	5.21336E-15	-25.4557311	140.41	
0.5	-5.51566	1.92180E-14	-24.1511063	133.21	
1	-5.51566	7.68721E-14	-22.76481193	125.56	
5	-5.51566	1.9218E-12	-19.5459361	107.81	
13.2	-5.51566	1.33942E-11	-17.60437827	97.10	Pc Minnelusa to Unkpapa/Sundance Burdock Area
14.45	-5.51566	1.60511E-11	-17.4234231	96.10	Pc Minnelusa to Unkpapa/Sundance Dewey Area
22.6	-5.51566	3.92632E-11	-16.52891211	91.17	
25	-5.51566	4.80451E-11	-16.32706028	90.05	
35	-5.51566	9.41684E-11	-15.6541158	86.34	
48.5	-5.51566	1.80823E-10	-15.00168433	82.74	
50.5	-5.51566	1.96043E-10	-14.92086525	82.30	
75	-5.51566	4.32406E-10	-14.1298357	77.94	
100	-5.51566	7.68721E-10	-13.55447155	74.76	
125	-5.51566	1.20113E-09	-13.10818445	72.30	
150	-5.51566	1.72962E-09	-12.74354134	70.29	
172	-5.51566	2.27419E-09	-12.46982297	68.78	
200	-5.51566	3.07489E-09	-12.16817719	67.12	

Calculated Pressure Rise vs. Distance (Diffusivity Equation) - Minnelusa Formation Based on 12 Years of Injection Activity at 75 GPM

$dp = -70.6 \left( \frac{qBu}{kh} \right) \left[ \ln(1688.388 \cdot por \cdot u \cdot ct \cdot rw^2 / kt) - 2s \right]$   
 dp= pressure differential  
 q= flowrate (STB/d)  
 B= formation volume factor (RB/STB)  
 u= viscosity (cp)  
 k= permeability (md)  
 h= reservoir thickness (feet)  
 por= formation effective porosity (percent)  
 ct= total matrix and fluid compressibility (1/psi)  
 rw= radius (feet)  
 t= injection time (hours)  
 s= skin factor (units)

where  
solve psi

3,977.14 bbl/d  
 1.01 RB/STB  
 0.74 cp  
 150 md  
 164 feet  
 0.1 fraction  
 6.50E-06 psi<sup>-1</sup>  
 variable feet  
 105216  
 0

proposed flow rate  
116 gpm

max flow rate		
170 gpm	5828.571 bbl/d	DW No. 1 Burdock Area based on Unkpapa/Sundance
234 gpm	8022.857 bbl/d	DW No.3 Dewey Area based on Unkpapa/Sundance
110 gpm	3771.429 bbl/d	DW No. 1. Burdock Area based on Madison
97 gpm	3325.714 bbl/d	DW No. 3 Dewey Area based on Madison

nearest potential pathway Burdock Area: Earl Darrow #1 3,900 feet away from the Class V injection wells in the Burdock Area.  
 through confining zone: Dewey Area: Dewey Fault 9,375 feet from the Class V injection wells in the Dewey Area

Term 1=  $-70.6(qBu/kh)$  Injection Rate (gpm)= 75 2571.428571 bbl/d  
 Term 2=  $(por \cdot u \cdot ct \cdot rw^2 / kt)$   
 dp= Term 1 \*  $\ln(1688.388 \cdot Term 2)$

Radius (rw) (ft)	Term 1	Term 2	$[\ln(1688.388 \cdot Term 2) - 2s]$	dp (psi)	
0.26042	-8.53088	2.06691E-15	-26.3809028	225.05	
50	-8.53088	7.61925E-11	-15.8659376	135.35	
475	-8.53088	6.87637E-09	-11.36335405	96.94	Pc=97.1 for Minn to Unpapa/Sundance Burdock Area
500	-8.53088	7.61925E-09	-11.26076746	96.06	Pc=96.1 for Minn to Unpapa/Sundance Dewey Area
18480	-8.53088	1.04082E-05	-4.041094963	34.47	Pc=34.8 for Minn to Madison Burdock Area
13200	-8.53088	5.31031E-06	-4.714039436	40.21	Pc=40.3 for Minn to Madison Dewey Area

Calculating max injection rate by determining the rate that extends the critical pressure to 1000 feet away from the nearest potential breach in confining zone:

2900	-12.50215	2.56311E-07	-7.745051622	96.83	Pc=97.1 for Minn to Unpapa/Sundance Burdock Area based in distance to Earl Darrow #1 of 3,900 from DW No. 1
8375	-17.20885	2.13767E-06	-5.62397094	96.78	Pc=96.1 for Minn to Unpapa/Sundance Dewey Area based in distance to Dewey Fault of 9,375 from DW No. 3
16250	-8.08963	8.04783E-06	-4.298287278	34.77	Pc=34.8 for Minn to Madison Burdock Area based in distance to Lance Nelson of 17,250 from DW No. 1
8375	-7.13358	2.13767E-06	-5.62397094	40.12	Pc=40.3 for Minn to Madison Dewey Area based in distance to Dewey Fault of 9,375 from DW No. 3