

# Implication of the Multiphase Influx in Well Control and Circulating System

(Implikasi Influx Multifasa Dalam Pengendalian Sumur Dan Sistem Sirkulasi)

Sonny Irawan<sup>1\*</sup>, Imros B. Kinif<sup>2</sup>, Fathaddin M. T.<sup>3</sup>, Zulfadli B. Zakaria<sup>4</sup>

<sup>1</sup>Petroleum Engineering Department, School of Mining and Geoscience, Nazarbayev University, Kazakhstan

<sup>2</sup>Glocal Network Sdn Bhd, Malaysia

<sup>3</sup>Petroleum Engineering Department, Faculty of Earth Technology and Energy, Indonesia

<sup>4</sup>Petronas Carigali Sdn Bhd, Malaysia

---

## Abstract

A multiphase flow system is commonly faced by oil and gas industries where it constituted of complex design and analysis [1]. Previous studies on the multiphase system have established a number of models including Hagerdon & Brown, Duns & Ros, Orkiszewki and Beggs & Brill [1]. Numerous studies have been carried out on the multiphase system related to production engineering [3]. However, the study on the multiphase system is found limited to be related to well control and drilling management. The multiphase system is interestingly important in well control especially during unwanted circumstances such as kick. Flow behavior and pattern might be different from one phase system where normally only gas kick is considered during design stage of the drilling campaign. Since the multiphase kick might represent different outcome compared to one phase system, an accurate calculation of multiphase kick is desired. Therefore, the purpose of this study is to observe the impact on the multiphase kick with on the pressure drop reading and its connection with a circulating system. The study will cover on Pressure drop calculation using Beggs & Brill correlation by consolidating all the data given from various sources; Identification of flow regime of the multiphase system for the base case with several reference pressure; Sensitivity analysis including the effect of different liquid content and liquid flow rate towards the pressure drop. The expected outcomes from this study are beneficial for well control management where necessary actions to prevent blowout.

**Keywords:** Well Control, Multiphase Influx, Circulating System, Pressure Drop, Kick

## Sari

Sistem aliran multifasa umumnya banyak dihadapi oleh industri minyak dan gas, di mana sistem aliran memerlukan suatu desain dan analisis yang kompleks. Sejumlah ilmuwan seperti Hagerdon & Brown, Duns & Ros, Orkiszewki dan Beggs & Brill telah meletakkan dasar-dasar model aliran multifasa di dunia perminyakan. Sejumlah penelitian aliran multifasa telah digunakan terkait dengan teknik produksi, namun studi tentang sistem multifasa terkait well control dan management pemboran masih sangat terbatas. Sistem aliran multifasa sangat penting di well control terutama untuk menjelaskan fenomena masuknya fluida yang tidak diinginkan kedalam lubang bor seperti kick. Perilaku dan pola aliran kick mungkin sangat berbeda antara aliran satu fasa dan aliran multifasa yang selama ini selalu menjadi acuan utama. Apabila terjadi kick maka asumsinya adalah alirannya satu fasa (gas atau air saja). Kick dengan aliran multifasa dan satu fasa tentunya akan menghasilkan sistem perhitungan penurunan tekanan yang berbeda, sehingga perhitungan yang sangat teliti diperlukan untuk memprediksi tekanan kick dikemudian hari. Oleh karena itu studi ini di fokuskan kepada pengamatan perubahan penurunan tekanan apabila terjadinya kick dengan aliran multifasa dan keterkaitannya dengan sistem sirkulasi fluida pemboran. Tujuan studi ini adalah: melakukan perhitungan penurunan tekanan dengan menggunakan persamaan Beggs & Brill dengan cara menggabungkan semua variasi data sumur, Mengidentifikasi pola aliran dari multifasa dan divariasikan terhadap berbagai tekanan referensi. Analisa sensitivitas yang meliputi pengaruh kandungan fluida kick dan laju aliran (flow rate) terhadap penurunan tekanan sumur. Hasil yang diharapkan dari studi ini manajemen well control pada saat pencegahan blowout.

**Kata-kata kunci:** Pengendalian Sumur, Influx Multifasa, Sistem Sirkulasi, Penurunan Tekanan, Letupan

\*Corresponding author

E-mail: irawan.sonny@nu.edu.kz

Tel: +(7) 771 441 3590

---

## I. INTRODUCTION

As the drill string penetrates a potential reservoir, an influx of formation fluids might enter the wellbore and a substantial amount of formation fluids will cause hazardous for the operation to continue [5]. This situation will leads to losing primary control which requires secondary control using BOP to take over. The formation fluids enter

the well during drilling can be in single-phase or two-phase form [10]. To understand the behavior of the multiphase fluid system can be challenging especially in predicting the implications of the multiphase system towards specific conditions [11, 12]. The multiphase flow encountered in exploration and production activities can be a combination of a natural gas phase, a hydrocarbon

liquid phase and a water phase [1]. Conceptually, in a multiphase flow system, the volume in a pipe filled by one phase fluid is often different from its proportion of the total volumetric flow rate. This is because for a standard two-phase flow of gas and liquid, flowing vertically upward, the gas flows faster than the liquid due to their different densities. This has created a slip or hold-up effect as the velocity between both phases is different. Hence the in-situ volume fraction will also differ from the input volume fraction of the pipe [13, 14]. Apart from that, the multiphase system has an association of distinguished flow patterns depending on the nature of flow and the quantity of these fluids contributed for each phase [11, 15]. This paper will discuss on how to observe the impact on the multiphase kick with on the pressure drop reading and its connection with a circulating system.

## II. METHOD

The types of flow regime can be classified into three (3) major groups which are segregated flow, intermittent flow and distributed flow as shown in Figure 1.

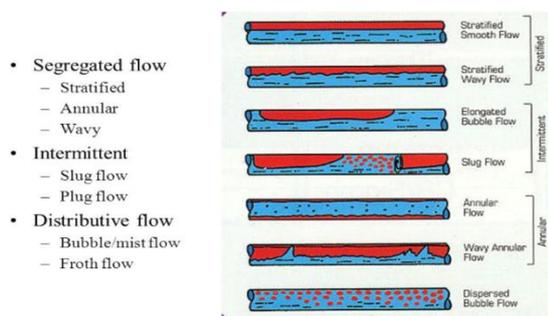


Figure 1. Horizontal Two-Phase Flow [14, 16]

There are several correlations have been introduced in the literature on calculating the pressure drop of multiphase including [1, 11, 18, 19]; Hagerdon & Brown correlation; Duns & Ros correlation; Orkiszewski correlation and Beggs & Brill correlation. For this study, the Beggs & Brill correlation is selected based on the accuracy criteria given by Masud Behnia in his study of multiphase correlations [18, 20]. The selected method represents the lowest average errors among others and provides flexibility of flow conditions [20]. Apart from that, the selection is justified with the applicability of the model towards well orientation (inclination angle) where the model can be applied for horizontal, vertical or inclined well [16]. The overall study flow as is shown in Figure 2.

The study was classified into five (5) phases of study:

Phase 1: Setting up the base cases

The base case is set up according to four (4)

distinctive reference pressures. The fluid data is gathered and analyzed. All pressures have different corresponding properties hence will give different sets of outcomes.

Phase 2: Sensitivity analysis of the liquid content

Once the base case for each pressure is established, the sensitivity analysis on the liquid content is carried out and the resulted pressure drops are monitored. The best fit line for each changes is correlated and listed.

Phase 3: Sensitivity analysis on the liquid flowrate

Apart from the liquid content, the sensitivity analysis is repeated similar to Phase 2 with changes in the liquid flowrate.

Phase 4: Hydraulic Power Analysis

Different pressure drops obtained from the previous phase are calculated and other related data are gathered and used in the calculation. Changes of a different set of pressure drops are analyzed and the best fit lines are correlated.

Phase 5: Result consolidation and comparison

The outcomes from the analysis are consolidated and compared with the base case(s).

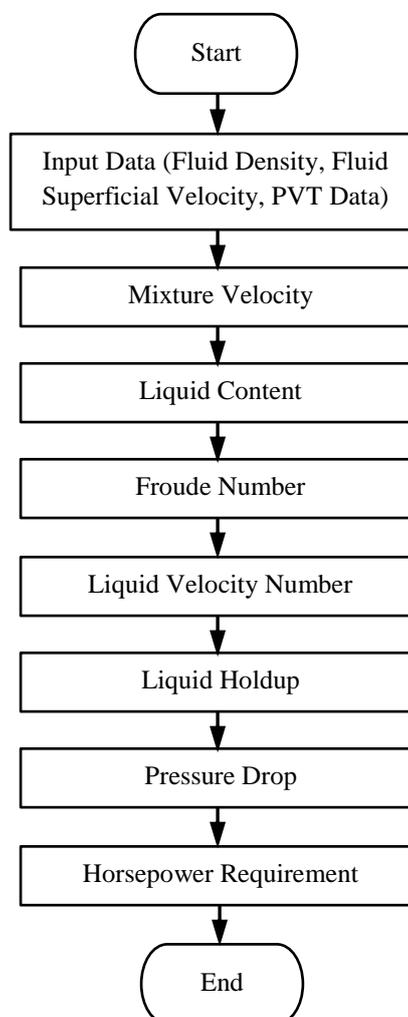


Figure 2. The Methodology of Study

### III. RESULTS AND DISCUSSION

Table 1 is the well and fluid properties information as input data. There are some additional information and assumptions that are required to complete the calculation for this study. The assumptions are made with appropriate justifications.

- 100 mole of hydrocarbon present in one medium for the study used to estimate the Specific Gravity (S.G.) of the gas.
- As a starting point of the study, the oil flow rate is selected from 1000 STBD for setting up the base case.
- Reservoir condition to be isothermal where the temperature of the reservoir is maintained at 155°F as stated in the well test report.
- Vertical-oriented well with 9 5/8" diameter of production casing and 12 1/4" of hole size for pressure drop calculation.
- Influx is estimated to have a height of 100ft and is used in the whole calculation and sensitivity analysis.

Table 1. Screening Criteria

Calculation Input Properties			
Well Properties	Total vertical depth	m	1636
	Pipe diameter	in	9 5/8
	Angle from horizontal	o	90
Formation Properties	Temperature	°F	155
	Pressure	psi	2116
Fluid Properties	Liquid Surface Tension	dynes/cm <sup>2</sup>	35
Other Properties	Gravity acceleration	ft/s <sup>2</sup>	32.15
	Gravity constant	ft <sup>3</sup> /lb.s <sup>2</sup>	32.17

#### Setting up the Base Case for Each Reference Pressure

The base case for individual reference pressure is finalized by applying Beggs & Brill method for determining the pressure drop. The summary of the pressure drop calculation can be found in Table 2.

From the calculation, it is found that changing of reference pressure for each base case will have a considerably large difference in the liquid content fraction, ranging from 24.3% to 52.2% of deviation. At the highest pressure of 1600 psi, the liquid content representing the biggest liquid content fraction among others (0.031) while at the lowest pressure, the liquid content fraction resulted in a nearly-zero (0.007). All four (4) base cases have produced a similar flow regime; segregated flow. As more analysis is carried out, the mixture velocity associated with flow regime has shown an

increasing trend ranging from 4.6 to 68.8 ft/s, with regards to change reference pressure from 1600 to 400 psi. Although the range is relatively wide, a similar flow regime is observed for all reference pressures. This is because the calculated Froude Number lied below the lower boundary,  $L_f$ .

In addition, lowering the reference pressure resulted in a decreasing pressure drop. This is because at lower pressure, more gas are liberated from the liquid hence resulting in a smaller fraction of liquid content. The outcomes for all distinctive pressures are collected and plotted as shown in Figure 3. An increase-polynomial trend is observed and the established relationship can be found in the plot. The correlation is beneficial in estimating the pressure drop due to the multiphase influx when the reference reservoir pressure is given.

Table 2. Base Case of Difference Reference Pressure

Base Case	Reference Pressure (psi)	Liquid content (fraction)	Flow Regime	Pressure Drop (psi)
1	1600	0.031	Segregated	1.91
2	1200	0.024	Segregated	1.58
3	800	0.015	Segregated	1.18
4	400	0.007	Segregated	0.68

#### Sensitivity Analysis of Pressure Drop with Changes in Liquid Content

The sensitivity analysis is carried out based on the minimum and maximum liquid content fraction, ranging from as lowest as 0.01 to 1.00. The result is plotted in Figure 4 and the relationship is established for each reference pressure. For reference pressure of 1600 psi, it is important to note that the maximum liquid content fraction that applicable for this analysis is 0.60. As shown in 4, the highest pressure drop calculated from the reference pressure is 2.5 psi occurring at a liquid content fraction of 0.01 and the lowest pressure drop is determined at liquid content fraction of 0.60 with -1.2psi. The trend is expected due to the fact that higher liquid content will lead to a higher mixture density. The higher mixture density exerts higher hydrostatic pressure hence the result from the sensitivity analysis is justified. By considering all sensitivity analysis for different reference pressure, it can be found that the pressure drop calculated shown a decreasing trend. The polynomial trend shown in Figures 4, 5, and 6 are approximately similar, however, a flattening trend can be observed in Figure 7 where the change of pressure drop is smaller. This can be concluded that at a lower reference pressure, the effect of liquid content on the pressure drop is smaller.

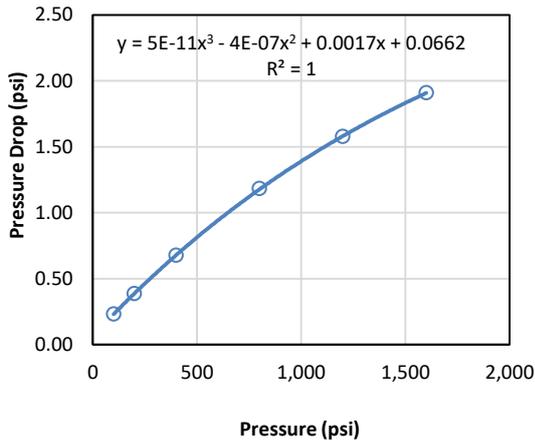


Figure 3. Relationship between Pressure Drop and Reference Pressure

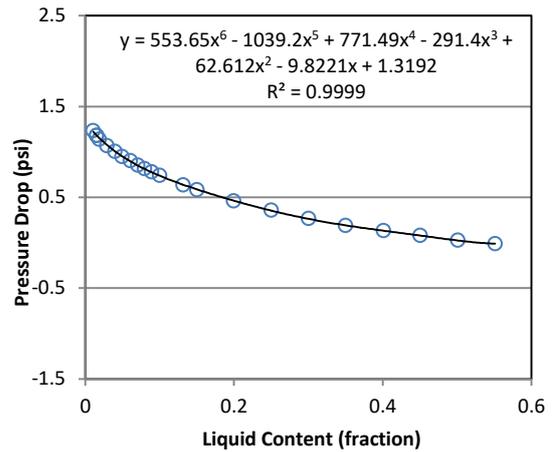


Figure 6. Pressure Drop Versus Liquid Content for Pressure 800 psi

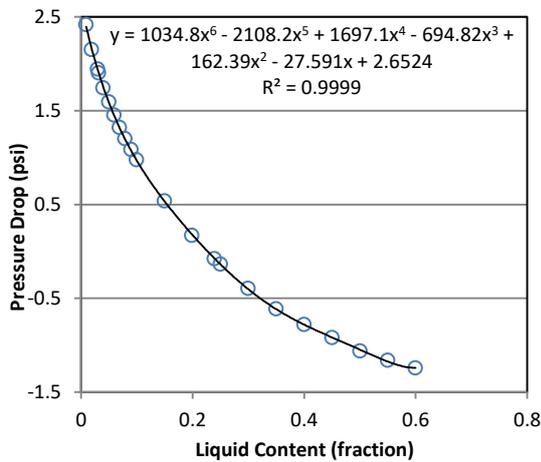


Figure 4. Pressure Drop Versus Liquid Content for Pressure 1600 psi

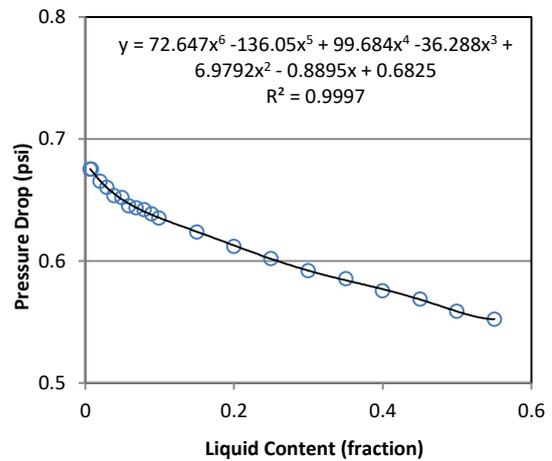


Figure 7. Pressure Drop Versus Liquid Content for Pressure 400 psi

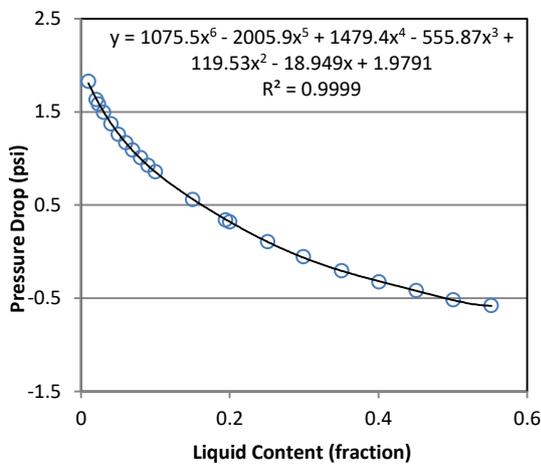


Figure 5. Pressure Drop Versus Liquid Content for Pressure 1200 psi

### Sensitivity Analysis of Liquid Flow Rate

In this section, the study focuses on how the oil flow rates with manipulating liquid content fraction influence the pressure drop calculation. The analysis is carried out according to given reference pressures. The analysis starts with an initial flow rate of 1000 STBD and complete at 10,000 STBD. The result in Table 3. According to the results, the flow regime starts to transform from segregated to distributed flow when the flow rate increased to 4000 STBD for all reference pressures. Apart from that, it can be found that at the lower flow rate, the flow regime is maintained as segregated flow regardless of reference pressure where the lower flow rate lay between 1000 to 3000 STBD. The intermittent flow is observed when the flow rate increases from 6000 STBD onwards and the liquid content fraction increases from approximately 0.03. A distributed type of flow can only be seen when

the flow rate is more than 3000 STBD and the liquid content fraction is lower than 0.03. Other than that, there is no distributed flow is observed and the transformation involves segregated and intermittent flow only. The sensitivity analysis has also revealed that the pressure drop is decreasing when the reference pressure decreases.

#### IV. CONCLUSIONS

For reference pressure of 1600 psi, the pressure drop increase by 29.8% when the flow rate change from 1000 STBD to 10000STBD at liquid content of 0.01. The incremental trend of pressure drop from the analysis has shown that the increases of flow rate in the flow system increases the fluid-pipe friction and consequently increase the total pressure drop.

At high flow rate (more than 3000 STBD) and low liquid content (less than 0.03), the determined flow regime is distributed flow while at a high flow rate (more than 5000 STBD) and high liquid content (more than 0.03), the flow is determined as an intermittent flow for all reference pressures.

#### REFERENCES

1. Brill, J.P., 1987, Multiphase Flow in Wells. *Journal of Petroleum Technology*, Volume 39:1.
2. Yahaya, A.U. and Gahtani, A.A. 2010. A Comparative Study between Empirical Correlations & Mechanistic Models of Vertical Multiphase Flow. The 2010 SPE/DGS Annual Technical Symposium and Exhibition, Al-Khobar, Saudi Arabia.
3. Khalid Aziz, G.W.G., Maria Fogarasi, 1972. Pressure Drop in Wells Producing Oil and Gas. *Journal of Canadian Petroleum*, Volume 11:3.
4. Drilling and Well Operations Volume 8, PETRONAS Procedures and Guidelines for Upstream Activities (PPGUA). 2013. 3.0.
5. Redmann, K.P. Jr., 1991. Understanding kick tolerance and its significance in drilling planning and execution. *Journal of SPE (Society of Petroleum Engineers) Drilling Engineering*, Volume: 6:4.
6. Grace, R.D., *Blowout and Well Control Handbook*. Elsevier 2003.
7. Santos, O., et al., 1995. Determination of Casing Setting Depth Using Kick Tolerance Concept. *Petroleum Computer Conference*, Houston, Texas.
8. Centre, A.D.S.W.C.T., *Well Control for the Rigs-site Drilling Team - Training Manual*. 2002.
9. Abd El Moniem, M.A. and A.H. El-Banbi, 2015. Proper Selection of Multiphase Flow Correlations. *SPE North Africa Technical Conference and Exhibition*, Cairo, Egypt.
10. Hasan, A.R., C.S. Kabir, and M. Sayarpour, 2004. A Basic Approach to Wellbore Two-Phase Flow Modeling. *The SPE Annual Technical Conference and Exhibition*, Houston.
11. A. Akintonia Sarah, U.A.J., Onuegbu Mary-Ann, 2014. Pressure Gradient Prediction of Multiphase Flow in Pipes. *British Journal of Applied Science and Technology*. 4(35): 4945-4958.
12. Lage, A.C.V.M. and R.W. Time, 2000. An Experimental and Theoretical Investigation of Upward Two-Phase Flow in Annuli. *SPE Asia Pacific Oil and Gas Conference and Exhibition*, Brisbane, Australia.
13. Johnson, A.B. and D.B. White, 1990. Gas-Rise Velocities during Kicks. *SPE Annual Technical Conference and Exhibition*, New Orleans.
14. Griffith, P. 1984, Multiphase Flow in Pipes. *Journal of Petroleum Technology*, volume 36:03.
15. Chierici, G.L., G.M. Ciucci, and G. Sclocchi, 1974. Two-Phase Vertical Flow in Oil Wells - Prediction of Pressure Drop. *Journal of Petroleum Technology*, volume 26:08.
16. H. Dale Beggs, J.P.B., 1973. A Study of Two-Phase Flow in Inclined Pipes. *Journal of Petroleum Technology*, Volume 25:05.
17. Orkiszewski, J., 1967. Predicting Two-Phase Pressure Drops in Vertical Pipe. *Journal of Petroleum Technology*, Volume 19:06.
18. Behnia, M., 1991, Most Accurate Two-Phase Pressure-Drop Correlation Identified. *Oil & Gas Journal*, 89(37).
19. Mukherjee, H. and J.P. Brill, 1983. Liquid Holdup Correlations for Inclined Two-Phase Flow. *Journal of Petroleum Technology*, Volume 35:05.
20. de Salis, J., et al., 1996. Multiphase Pumping - Operation and Control. *SPE Annual Technical Conference and Exhibition*, Denver, Colorado.

Table 3. Pressure Drop and Flow Regime at Different Liquid Content with Pressure 1600 psi

Liquid Content (fraction)	Pressure : 1600 psi									
	1000 STBD	2000 STBD	3000 STBD	4000 STBD	5000 STBD	6000 STBD	7000 STBD	8000 STBD	9000 STBD	10000 STBD
0.01	2.42	2.50	2.55	3.01	3.03	3.05	3.07	3.09	3.11	3.14
0.02	2.15	2.24	2.30	2.34	2.38	2.84	3.02	3.03	3.04	3.05
0.03	1.94	2.04	2.11	2.16	2.20	2.23	2.78	2.80	2.82	3.01
0.04	1.76	1.88	1.95	2.00	2.05	2.08	2.72	2.73	2.75	2.92
0.05	1.60	1.73	1.81	1.87	1.91	1.95	1.98	2.68	2.70	2.85
0.06	1.45	1.60	1.69	1.75	1.80	1.84	1.87	2.63	2.65	2.78
0.07	1.32	1.48	1.57	1.64	1.69	1.73	1.77	2.59	2.61	2.73
0.08	1.20	1.37	1.47	1.54	1.59	1.64	1.68	1.71	2.57	2.68
0.09	1.09	1.27	1.37	1.44	1.50	1.55	1.59	1.62	2.53	2.63
0.10	0.98	1.17	1.28	1.36	1.42	1.46	1.51	1.54	2.50	2.58
0.15	0.53	0.76	0.89	0.98	1.05	1.11	1.16	1.20	2.35	2.38
0.20	0.17	0.43	0.58	0.69	0.77	0.83	0.89	0.94	2.22	2.20
0.24	-0.07	0.22	0.38	0.50	0.58	0.65	0.71	0.77	2.13	2.07
0.25	-0.13	0.17	0.33	0.45	0.54	0.61	0.67	0.72	2.11	2.04
0.30	-0.38	-0.06	0.13	0.25	0.35	0.42	0.49	0.55	2.00	1.90
0.35	-0.59	-0.24	-0.05	0.09	0.19	0.27	0.34	0.40	1.91	1.78
0.40	-0.77	-0.40	-0.19	-0.05	0.06	0.15	0.22	0.29	1.82	1.69
0.45	-0.92	-0.53	-0.31	-0.16	-0.05	0.05	0.12	0.19	1.74	1.66
0.50	-1.05	-0.63	-0.41	-0.25	-0.13	-0.03	0.05	0.12	1.66	1.31
0.55	-1.15	-0.72	-0.48	-0.32	-0.19	-0.09	-0.01	0.06	1.59	1.30
0.60	-1.24	-0.79	-0.54	-0.37	-0.24	-0.14	-0.05	0.02	1.52	1.20
0.65		-0.84	-0.58	-0.41	-0.28	-0.17	-0.08	0.00	1.46	1.94
0.70		-0.87	-0.61	-0.43	-0.29	-0.18	-0.09	-0.01	1.40	1.28
0.75		-0.89	-0.62	-0.44	-0.30	-0.18	-0.09	-0.01	1.34	1.21
0.80		-0.90	-0.62	-0.43	-0.29	-0.17	-0.08	0.00	1.28	1.16
0.85		-0.89	-0.61	-0.42	-0.27	-0.15	-0.05	0.03	1.23	1.14
0.90		-0.88	-0.59	-0.39	-0.24	-0.12	-0.02	0.07	1.18	1.12
0.95		-0.85	-0.55	-0.35	-0.20	-0.07	0.03	0.11	1.13	1.11
1.00		-0.81	-0.50	-0.30	-0.14	-0.02	0.08	0.17	1.09	1.11

Denotation of different types of flow regime

- Segregated Flow
- Intermitted Flow
- Distributed Flow