Formulae to Estimate Peak Effluent Flows from Brazilian Dams Break in 21th Century

Carolina Icho[1], Rodolfo Scarati[2], José Bernardino[3]

University of São Paulo [123]; Lima, Perú[1]; São Paulo, Brasil[23]

carolina.icho@usp.br[1]

Abstract: To predict the flood after a dam failure, many computational and empirical approaches have been developed throughout history. All those includes a certain number of parameters and are intended to help engineers in quick estimates and planning more detailed studies. We aimed to evaluate the different empirical formulas proposed by researchers to estimate the outflow peak dambreak situations and compare the results in two different case studies, the overtopping and piping failure of Jurumirim and Chavantes dams. In this study, Hec-Ras software was implemented and used as reference to calculate the discharge peaks. Considering the large amount of available formulas, a statistical analysis where employed to evaluate and classify the results.

Keywords: Dam break, flood propagation, Hec-Ras computational modeling, dam safety, rupture parameters.

Methods

Author	Formula	Depends on
Pierce (2008)[1]	$Qp = 0.784 \times Hw^{2.668}$	Hw
Pierce (2008)[2]	$Qp = 2.325 \times Ln(Hw)^{6.405}$	Hw
Pierce (2008)[3]	$Qp = 0.00919 \times V^{0.745}$	V
Singh and Snorrason (1984)[1]	$Qp = 1.776 \times V^{0.47}$	V
U. S. Bureau of Reclamation (1982) Enveloped Equation	$Qp = 19.1 \times hw^{1.85}$	hw
Soil Conservation Service (1981) apud Wahl (2008)	$Qp = 16.6 \times hw^{1.85}$	hw
Singh and Snorrason (1984)[2]	$Qp = 13.4 \times H^{1.99}$	H
Singh and Snorrason (1984)[3]	$Qp = 1.776 \times V^{0.47}$	V
Costa (1985)[1]	$Qp = 1.122 \times V^{0.57}$	V
Evans (1986)	$Qp = 0.72 \times V^{0.53}$	V
Lou (1981) apud Faria (2019)	$Qp = 7.683 \times H^{1.909}$	H
Froehlich (1995b)	$Qp = 0.607 \times V^{0.295} \times hw^{1.24}$	V, hw
MacDonald and Langridge - Monopolis (1984)	$Qp = 1.154 \times (V \times hw)^{0.412}$	V, hw
MacDonald and Langridge - Monopolis (1984) Enveloped equation	$Qp = 3.85 \times (V \times hw)^{0.411}$	V, hw
Hagen(1982)[1]	$Qp = 0.54 \times (V \times H)^{0.5}$	V, H
Hagen(1982)[2]	$Qp = 1.205 \times (H \times V)^{0.48}$	V, H
Vertedor de soleira espessa - Singh (1996) apud Faria (2019)	$Qp = 1.7 \times b \times h^{\frac{3}{2}}$	b,h
Costa (1985)[2]	$Qp = 0.981 \times (S \times H)^{0.42}$	S,H
Costa (1985) Envolved Equation	$Qp = 2.634 \times (S \times H)^{0.44}$	S,H
Wetmore e Fread (1981) apud Faria (2019)	$Qp = 1.7 \times Bt \times \left\{ \frac{1.94 \times \frac{As}{Bb}}{Tp + \left[\frac{1.94 \times As}{Bb \times \sqrt{H}}\right]} \right\}^3$	As,H
Xu and Zhang (2009)	$\frac{Qp}{\sqrt{g} \times V^{5/3}} = 0.175 \times \left(\frac{H}{Hr}\right)^{0.199} \times \left(\frac{V^{1/3}}{hw}\right)^{-1.274} \times e^{B4}$	V,H,Hw
Mohamed (2001)[2]	$Qp = 0.98 \times A \times \sqrt{2 \times g \times (Hw - Hp)}$ (Only Piping)	A,Hw,Hp
Apud NRCS (2005)	$Qp = 65 \times Hw^{1.85}$ $Qp = 1.1 \times Br^{1.25}$	Hw, V,Ab
Saint Venant apud Faria (2019)	$Qp = \frac{8}{27} \times b \times \sqrt{g} \times Y_{medio}^{\frac{3}{2}}$	b,Hw,hmin-op
Mohamed (2001)[1]	$Qp = 3 \times b \times (Hw - Hc)^{1.5}$	b,Hw,Hc
Macchione (2008)[1]	$Qp = \left(\frac{1}{2} \times g\right)^{1/2} \times \left(\frac{4}{5} \times (Hw - Y)\right)^{5/2} \times \tan(\beta)$	Hw,B,m,H
Macchione(2008)[2]	$Qp = \left(\frac{1}{2} \times g\right)^{1/2} \times (Hw(Hw - 2Y))^{3/2} \times (Hw - Y)^{-1/2} \times \tan(\beta)$	Hw,B,m,H

Table 1. Formulas to estimate the peak effluent flow from a rupture
Source: Author

Results

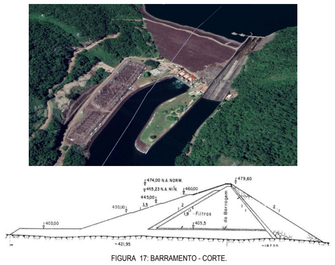

Figure 2. Section plan of the Jurumirim concrete dam. **Source:** FCTH (2003)

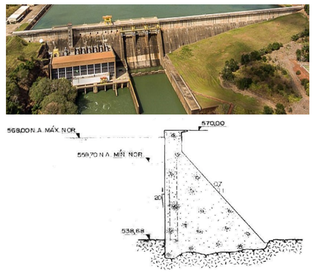

Figure 3. Elevation and section plan of the Chavantes dam. **Source:** FCTH (2003)

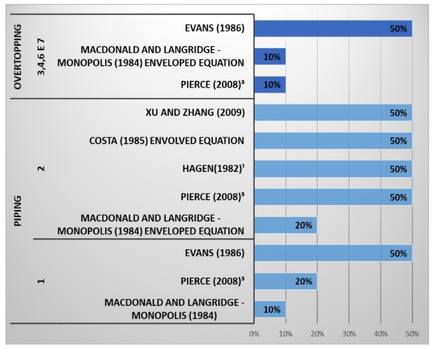

Figure 4. Degree of uncertainty between the results provided in each case by the HEC-RAS software and those generated by the proposed in formulas in Chavantes dam. **Source:** Author

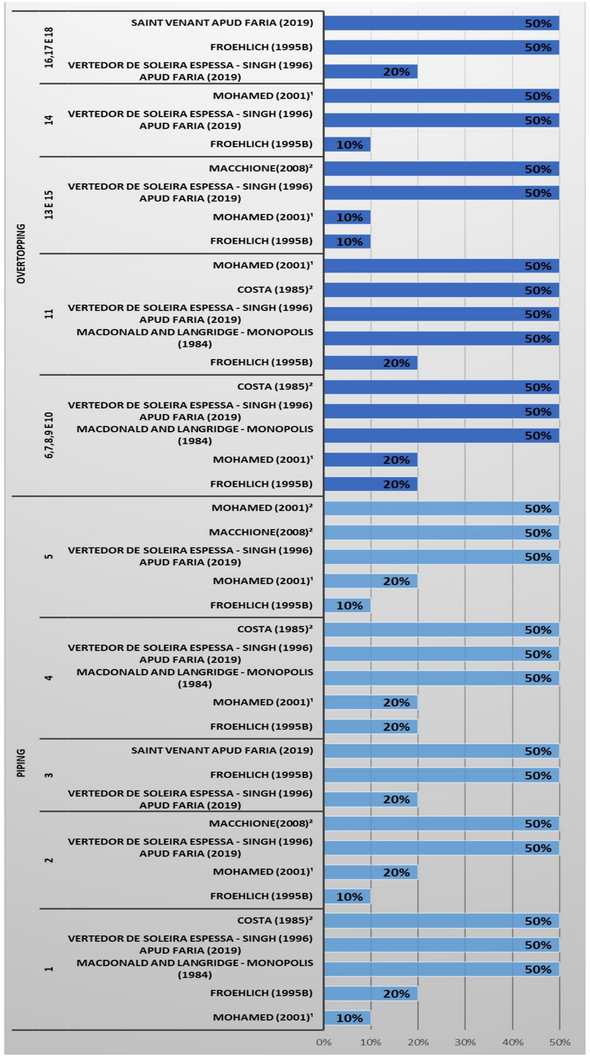

Figure 5. Degree of uncertainty between the results provided in each case by the HEC-RAS software and those generated by the proposed in formulas in Jurumirim dam. **Source:** Author

Conclusions

- Summarized the most important contributions to predict dam break flow
- More than 50 formulations were found in the literature
- There were limitations in some formulas and the software
- We can select 3 to 5 formulas that are really closer to the results of the HEC-RAS software simulated in rupture by Piping and Overtopping.
- the amount of parameters considered what let us to postulate that the correct selection of information to use with the formulas is more important than detailed parametrization

	Jurumirim Dam
1	Froehlich (1995B)
	Singh (1996)
2	Mohamed (2001)[1]
3	U.S. Army Corps of Engineering (Saint Venant)
	Macchione (2008)[2]
	Costa (1985)[2]
	MacDonald (1984)

	Chavantes Dam
1	Pierce (2008)[3]
2	Evans (1986)
	MacDonald Enveloped Equation (1984)
3	Xu and Zhang (2009)
	Costa Enveloped Equation (1985)
	Hagen (1982)[1]
	MacDonald (1984)

Table 2. Authors with the most precise formulas for each dam. **Source:** Author

Bibliography

ANA, Agencia Nacional de Águas. Manual Básico HEC-RAS 5.0.3 para Ruptura de Barragens, 2018.
ANA, Agencia Nacional de Águas. Manual de Políticas de Segurança de Barragens para Entidades Fiscalizadoras, 2016.
ANA, Agencia Nacional del Agua. Reglamento de Seguridad de Presas Publicas de Embalse de Agua, 2019.
Association of State Dam Safety Officials. Summary of State Laws and Regulations on Dam Safety, 2000.
Association of State Dam Safety Officials. Summary of State Laws and Regulations on Dam Safety, 2000.
BRATER, E. Hydraulics. [In] Urquhart LC, ed: Civil Engineering Handbook. New York, McG'aw-Hill, p. 1-107, 1959.
Brunner, G. W. (1995). HEC-RAS River Analysis System. Hydraulic Reference Manual. Version 1.0. Hydrologic Engineering Center Davis CA.
COSTA, J. E. Floods from dam failures. US Geological Survey, 1985. v. 560).
Faria, F. L., Silva, M. B., de M Reis, M., & Amorim, J. C. (2019). Metodologia para obtenção do hidrograma para simulação de ruptura de barragens. Revista Militar de Ciência e Tecnologia, 36(3).
FCTH, Fundação Centro Tecnológico de Hidráulica; Duke-Energy Internacional. Modelação da Propagação de Cheias Ocasionadas por Rompimento de Barragens na Cadeia de Geração do Rio Paranapanema, 2003.
FROEHLICH, D. C. Embankment dam breach parameters and their uncertainties. Journal of Hydraulic Engineering, 134, n. 12, p. 1708-1721, 2008.
FROEHLICH, D. C. Peak outflow from breached embankment dam. Journal of water Resources Planning and management, 121, n. 1, p. 90-97, 1995.
GRAHAM, W., Channel and Valley Changes Resulting from Dam Failure. Proceedings of the 2nd CADAM Workshop, Munique, Alemanha, 1998.
Hagen, V. K. Re-evaluation of design floods and dam safety. 14th Congress of Int. Commission on Large Dams, 1982.
LAURIANO, A. W. Estudo de Ruptura da Barragem de Funil: comparação entre os modelos FLDWAV e HEC-RAS. 2009.
MACCHIONE, F. Model for predicting floods due to earthen dam breaching. I: Formulation and evaluation. Journal of Hydraulic Engineering, 134, n. 12, p. 1688-1696, 2008.
MACDONALD, T. C.; LANGRIDGE-MONOPOLIS, J. Breaching charateristics of dam failures. Journal of Hydraulic Engineering, 110, n. 5, p. 567-586, 1984.
Mbajiorgu, C. C. Flood Inundation Simulation using HEC-RAS Hydrologic Model: A Case Study of Oyun River, Nigeria; 2017.
MOHAMED, M.; SAMUELS, P.; MORRIS, M. Uncertainties In Dam Failure Modelling With The US NSW BREACH Model. WIT Transactions on Ecology and the Environment, 50, 2001.
Oliveira, R A F. Propagação de Ondas de Despacho e Controle de Inundações da bacia do Paraíba do Sul. Dissertação - Msc. Engenharia Civil, Universidade Federal do Rio de Janeiro, COPPE, 2005.
PIERCE, M. W.; THORNTON, C. I.; ABT, S. R. Predicting peak outflow from breached embankment dams. Journal of Hydrologic Engineering, 15, n. 5, p. 338-349, 2010.
Silva, T. A. D. Modelagem hidráulica do canal do Rio Granjeiro, Crato/CE, utilizando o programa computacional HEC-RAS, 2013.
SINGH, V. Dam Breach Modeling Technology, 1996. Kluwer, Dordrecht, the Netherlands.
SINGH, V. P. Dam breach modeling technology. Springer Science & Business Media, 2013. 9401587477.
Singh, V. P. Dam breach modeling technology. Springer Science & Business Media, 2013.
Soil Conservation Service (SCS), 1981. "Simplified dam-breach routing procedure." Tech. Release No. 66 (Rev. 1), 39.
USDA, United States Department of Agriculture. Earth Dams and Reservoirs TR-60. Conservation Engineering Division, 2005.
XU, Y.; ZHANG, L. Breaching parameters for earth and rockfill dams. Journal of Geotechnical and Geoenvironmental Engineering, 135, n. 12, p. 1957-1970, 2009.

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