This is an authorized facsimile, made from the microfilm master copy of the original dissertation or masters thesis published by UMI.

The bibliographic information for this thesis is contained in UMI's Dissertation Abstracts database, the only central source for accessing almost every doctoral dissertation accepted in North America since 1861.

UMI Dissertation Information Service

University Microfilms International A Bell & Howell Information Company 300 N. Zeeb Road, Ann Arbor, Michigan 48106 800-521-0600 OR 313/761-4700

Printed in 1987 by xerographic process on acid-free paper

TABLE OF CONTENTS

ACKNOWLEDGMENTS 11 LIST OF TABLES 11 LIST OF FIGURES 11 LIST OF FIGURES 11 LIST OF SYMBOLS 11 LIST OF SYMBOLS 11 ABSTRACT 11 Chapter 1 I. INTRODUCTION 1 II. REVIEW OF LITERATURE 4 Types of fluids 4 Newtonian fluid, curve D 5 Bingham plastic fluid, curve A 5 Pseudoplastic and dilatant fluids, curves B & C 5 Characteristics of debris flows 11 Johnson's Bingham model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEERIS FLOW 17 Flow regimes 11 Applicability of Saint-Venant equations to 11 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEERIS FLOW 17 Flow regimes 12 Applicability of Saint-Venant equations to laminar flow in open channel 17 Saint-Venant equations 19 Continuity equation derivation 22 Friction slope approach for deriving the equ																			Page
LIST OF TABLES vi LIST OF FIGURES vii LIST OF SYMEOLS ix ABSTRACT ix ABSTRACT xiii Chapter 1 II. INTRODUCTION 1 II. REVIEW OF LITERATURE 4 Mewtonian fluid, curve D 5 Bingham plastic fluid, curve A 5 Pseudoplastic and dilatant fluids, curves B & C 5 Characteristics of debris flows 6 Analytical approaches to debris flows 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discrimination approach for deriving the equation 30 Classification criteria 31	ACKNOWL	DGMENTS		•	•	•	•	٠		•	•	•			•	•	•	٠	ii
LIST OF FIGURES vii LIST OF SYMBOLS ix ABSTRACT xiii Chapter 1 I. INTRODUCTION 1 II. REVIEW OF LITERATURE 4 Types of fluids 4 Newtonian fluid, curve D 5 Bingham plastic fluid, curve A 5 Pseudoplastic and dilatant fluids, curves B & C 5 Characteristics of debris flows 11 Johnson's Bingham model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 11 Iminar flow in open channel 12 Flow regimes 12 Firiction slope approach for deriving the equation of motion 22 Friction slope approach for deriving the equation of motion for open channel debris flow 25 Determination of type of the Saint-Venant 25 Determination of or open channel debris flow 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Diseriminate calculation	LIST OF	TABLES	• 57	•	•	•	•			٠	•	•	•	•		•	•	(• .)	vi
LIST OF SYMBOLS ix ABSTRACT xiii Chapter . xiii I. INTRODUCTION 1 II. REVIEW OF LITERATURE 4 Types of fluids 4 Newtonian fluid, curve D 5 Bingham plastic fluid, curve A 5 Pseudoplastic and dilatant fluids, curves B & C 5 Characteristics of debris flows 11 Jahnson's Bingham model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 25 Determination of type of the Saint-Venant 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminate calculation 30 Discriminate calculation 31	LIST OF	FIGURES	٠	•	•	•	•	•	٠	(6)		٠	•				•	•	vii
ABSTRACT	LIST OF	SYMBOLS	•	•	•	•	•	•	•	٠	•	•	•	•	•	•	•	٠	ix
Chapter I. INTRODUCTION II. REVIEW OF LITERATURE II. REVIEW OF LITERATURE II. REVIEW OF LITERATURE II. REVIEW OF LITERATURE II. Types of fluids II. Contemportation of the state of the st	ABSTRACT	r.		•	•	•	•	•	•	•	•	•	•			•	•		xiii
I. INTRODUCTION	Chapter																		
II. REVIEW OF LITERATURE	I.	INTRODU	CTION	ſ	•	•	•	•	•	·	•	٠	•	•	•	•	•	٠	1
Types of fluids 4 Newtonian fluid, curve D 5 Bingham plastic fluid, curve A 5 Pseudoplastic and dilatant fluids, curves B & C 5 Characteristics of debris flows 6 Analytical approaches to debris flows 11 Takahashi's dilatant model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 17 Saint-Venant equations 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31	II.	REVIEW	OF LI	TE	RAT	URE	•	٠	•	•	•	•	•	•	•	•	•	•	4
Newtonian fluid, curve D. 5 Bingham plastic fluid, curve A. 5 Pseudoplastic and dilatant fluids, curves B & C. 5 Characteristics of debris flows. 6 Analytical approaches to debris flows. 11 Takahashi's dilatant model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31		Ty	pes o	f	flu	ids													4
Bingham plastic fluid, curve A 5 Pseudoplastic and dilatant fluids, curves B & C 5 Characteristics of debris flows 6 Analytical approaches to debris flows 11 Takahashi's dilatant model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 17 Saint-Venant equations 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31		Ne	wtoni	an	fl	uid,	, c	urv	e D										5
Pseudoplastic and dilatant fluids, curves B & C 5 Characteristics of debris flows 6 Analytical approaches to debris flows 11 Takahashi's dilatant model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 17 Saint-Venant equations 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31		Bi	ngham	p	las	tic	fl	uid	, c	urv	e A								5
Characteristics of debris flows		Ps	eudop	1a	sti	c ar	nd	dil	ata	nt	flu	ids	, 6	urv	es	B &	С		5
Analytical approaches to debris flows		Ch	aract	er	ist:	ics	of	de	bri	s f	low	s.							6
Takahashi's dilatant model 11 Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 17 Saint-Venant flow in open channel 17 Saint-Venant equations 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31		An	alyti	ca	1 aj	ppro	Dac	hes	to	de	bri	s f	low	s					11
Johnson's Bingham model 13 III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes 17 Applicability of Saint-Venant equations to 17 Iaminar flow in open channel 17 Saint-Venant equations 17 Continuity equation derivation 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31		, Ta	kahas	hi	's (1114	ata	nt	mod	el								•	11
III. DIFFERENTIAL EQUATION DESCRIBING OPEN CHANNEL DEBRIS FLOW 17 Flow regimes		Jo	hnson	's	Bin	ngha	am	mod	el	•	•	•	•	•	•	•	•	•	13
Flow regimes 17 Applicability of Saint-Venant equations to 17 laminar flow in open channel 17 Saint-Venant equations 17 Saint-Venant equations 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31	III.	DIFFERE	NTIAL	E	QUA	rior	D	ESC	RIB	ING	OP	EN	CHA	NNE	LI	EBR	IS	FLO	DW 17
Applicability of Saint-Venant equations to laminar flow in open channel. 17 Saint-Venant equations 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation of motion for open channel debris flow 25 Determination of type of the Saint-Venant partial differential equation 30 Classification criteria 30 Discriminant calculation 31		F1	ow re	gi	mes														17
laminar flow in open channel 17 Saint-Venant equations 19 Continuity equation derivation 20 Equation of motion 22 Friction slope approach for deriving the equation 25 Determination of type of the Saint-Venant 30 Classification criteria 30 Discriminant calculation 31		Ap	plica	bi	lit	y of	E S.	ain	t-V	ena	nt	equ	ati	ons	to	,			1201
Saint-Venant equations			lamin	ar	fl	w :	In	ope	n c	han	nel				-	-	2	022	17
Continuity equation derivation		Sa	int-V	en	ant	equ	at	ion	s										19
Equation of motion		Co	ntinu	it	y e	guat	io	n d	eri	vat	ion								20
Friction slope approach for deriving the equation of motion for open channel debris flow		Eq	uatio	n	of 1	not	Lon												22
of motion for open channel debris flow		Fr	ictio	n	slo	be a	app	roa	ch	for	de	riv	ing	th	e e	qua	tic	'n	
partial differential equation		De	of no	ti	on	for	oF	en	cha	nne	1 d	ebr	is	flo	w		•		25
Classification criteria		De	cermi	na	110	i oi		ype	OI	En	8 3	ain	E-V	ena	nt				20
Discriminant calculation		C1	parti	ar	all	Liei	ren	tia	i e	qua	LIO	n	•	•	•	•	•	•	30
UISCRIMINANE CALCULATION 31		Di	assii	10	atte		1.0.11	lat	14	•	•	•	•	•	•	•	•	•	21
		DI	scrim	un	ant	ca	Leu	Iat.	TOU	•	•	•	•		•	•	•	•	31
IV. MODEL FORMULATION	IV.	MODEL F	ORMUL	AT	ION		•	•	•	•	•	•	•	•	•	•	•	•	32
The Chezy equation		The	e Che	zy	equ	att	Lon	•	Tak		.i.	•		•	•	•	•	•	32
coefficient (k) and Chezy coefficient (C)		Ae	coeff	ic	ien	= ()	c)	and	Ch	ezy	co	eff	ici	ent	(0).			33
Complementary equations to use - Derivation of equations for the steady laminar flow of a thin		Co	mplem equat	io	tary	r ed	the	tion e s	ns tea	to	use lam	- ina	Der r f	iva low	tic	n o a	f	n	
sheet of viscous liquid with a free surface			sheet	0	fv	Isco	ous	11	qui	dw	ith	a	fre	e s	urf	ace			35
Velocity distribution		Ve	locit	y	dis	tril	ut	ion											35

iii

••

Ch	la	p	t	e	r	

IV. (continued)

					4								
	Navier-Stokes equation	lon	in	x-	di	rect	ion	an	d				
	two dimensional												36
	Rate of flow per uni	it w	id	th						10			37
	Reynolds number .											-	38
	The Froude number			÷.	0.00								39
	Chezy coefficient co	mou	ita	tic	n i	for	deb	ris	f	low			200.00
	based on Sharp and	I Ne	b1	es	dat	ta (195	3)					39
	Pierson (1981)										÷.		40
	Takabashi (1980)	•	•		1			÷.		•	•	•	40
	First set of data	•	•	•	1		•		•	•	•	•	41
	Second set of data	•	•	•	•	•	•	•	•	•	•	•	41
	First set of data	•	•	•	•	•	•	•	•	•	•	•	12
	Second set of data	•	•	•	•	•	•	•	•	•	•	•	42
	Babbit and Coldwall	•	•	•	•	•	•	•	•	•	•	•	43
	Least square fit to	· he	·	· .		1.	· · .	-i-	.:	•	•	۰.	45
	Least square iit to	ODL	ai		ne	bes	CI	era	LI	on-			10
	ship for the chezy	r cc	ber	IIC	ler	ILS	C	•	•	•	•	٠	43
	Friction factor f	٠	•	.:		.*	•	٠,	:	٠.	•	•	41
	Relationship between	i, th	ie	1 Lu	10	den	SIL	у((Q	and			
	its viscosity (µ)	:	•	•	٠	•				•	•	•	50
	Basis for the model	k/F	2	•	•	•	•	٠	•	•	•	•	51
	k value		•	•	•				•			•	51
	Equations defining of	lebr	is	fl	W0.	•	•	•			•		52
-													
٧.	THE DEBRIS FLOW COMPUTER	MOL	DEL			•							54
	agent agent and a set of the												363530
	Generalities	•	•		•		•	•	٠		٠	•	54
	Modifications made t	:0 0	ori	gin	al	pro	gra	m			•		57
	General change .				•						•		58
	Normal depth .									•	•		61
	Steady spatially van	ried	l f	low									62
	Euler method .												62
	Computer program for	so	1v	ing	tł	ne f	unc	tio	n	(F)			
	given by Equation	72											64
	and the second second second second												
VI.	APPLICATION OF THE COMPUT	ER	MO	DEL									67
	Relationship between	de	br	is	flo	w d	ept	h					
	and water flow dep	th											68
	Illustrative example	s											72
	Example 1 .												72
	Example 2												74
	Example 3 .												83
	Example 4	10				-	1.1						86
	General discussion			100									92
	COLTRY TOO DINA DO ENOUS	1	÷.,	ci a	101	1	-						

Page

TABLE OF CONTENTS (continued)

Chapter		Page
VII. SUMMARY	, CONCLUSIONS AND RECOMMENDATIONS	94
REFERENCES		96
APPENDIXES		99
Appendix A.	Computer Program Lists	100
Appendix B.	Example 1 • • • • • • • • • • • • • • • • • •	109
Appendix C.	Example 2	117
Appendix D.	Example 3	123
Appendix E.	Example 4	137
VITA · · · ·		144

There's county frequency and a first strength from the

in a share the two states the off they be