USING EII PHYSICAL INTEGRITY SCORES TO PREDICT RGA STREAM STABILITY SCORES.

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Abstract

Environmental Integrity Index (EII) physical integrity data were compared to Rapid Geomorphic Assessment (RGA) stream stability score by multiple linear regression and logistic regression analysis to enable prediction of stream stability index scores for watersheds where only EII data is available. EII physical integrity data could not accurately predict stability classes by either regression method.

Introduction

The City of Austin Environmental Resource Management Division (ERM) assesses 47 watersheds throughout the greater Austin area on a rotating 3-year basis using the Environmental Integrity Index, or EII (COA 1997, COA 2003). Approximately 4 spatially distributed sample sites are used to assess each watershed. At each site, a visual assessment of existing erosion-related in-stream and riparian conditions is completed for 10 parameters (Table 1), adapted from EPA protocols (Barbour and Striblings 1991). Additionally, a comprehensive evaluation of the stability and erosion occurring within stream reaches is conducted using the method developed for the U.S. Department of Agriculture (Pfankuch 1975). Completion of the physical habitat and Pfankuch assessments at each site is relatively quick, and the 47 watersheds included in the EII have been assessed approximately 3 times from 1996 to present.

Table 1. Physical habitat quality and channel assessment parameters.

EPA Physical Habitat	Pfankuch Channel Assessment
Epifaunal Substrate/Available Cover	Landform Slope
Embeddedness	Mass Wasting
Velocity/Depth Regimes	Debris Jam Potential
Sediment Deposition	Bank Protection from Vegetation
Channel Flow Status	Degree of Entrechment
Channel Alteration	Bank Rock Content
Frequency of Riffles	Obstructions, Deflections and Sediment Traps
Bank Stability	Cutting
Vegetative Protection	Deposition
Riparian Vegetative Zone Width	Rock Angularity
	Brightness
	Consolidation
	Bottom Size Distribution/% Stable Materials
	Scouring and Deposition
	Clinging Aquatic Vegetation

For watersheds included in phase I of the City of Austin master plan (COA 2001), consultants completed rapid geomorphic assessments (RGA) by stream reach to generate watershed stability index (SI) scores describing the physical stability of the reach (Table 2) in 1997 (Chan & Associates 1997). The 18 watersheds were divided into 5-21 stream reaches per watershed, starting at the mouth of the watershed and assessing upstream. The intensive RGA requires more staff time in the field to complete than the EII physical habitat or Pfankuch assessments. RGA have not been conducted for all phase II or III watersheds. EII sample locations do not match the consultant-generated RGA stream reaches for phase I watersheds (Figure 1). Consultants performed RGA on Onion Creek in 2002.

Table 2. Stability Index (SI) values, ranging from stable (0) to most unstable (1).

SI	Condition
0.0 – 0.2	Stable
0.2 – 0.4	Transitional
> 0.4	In adjustment

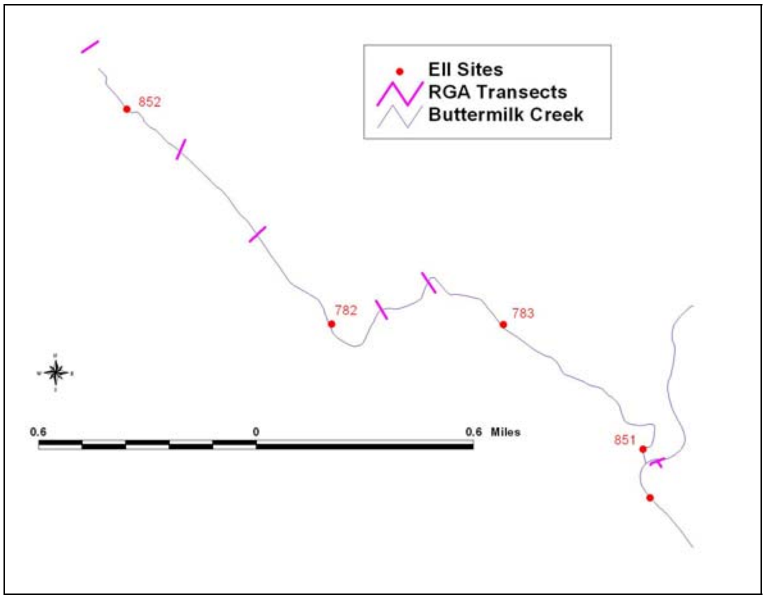

Figure 1. Example of non-matching EII sites and RGA reaches using Buttermilk Creek (flowing from northwest to southeast). The most downstream reach contains two EII sites, although reaches in the middle of the watershed contain none.

SI values and at least some of the EII physical habitat measures are expected to be highly correlated. If SI values can be predicted with reasonable accuracy from EII physical habitat measures, then SI values can be estimated for the remaining phase II and III watersheds more quickly and at a reduced cost than hiring consultants to perform stream corridor walks.

Methods

Multiple linear regression and logistic regression analysis were used to predict SI values from EII physical habitat and Pfankuch data for phase I watersheds. Because EII site locations and RGA reaches are not identical, two methods for assigning EII site data to RGA reaches were considered (Figure 2, Table 3).

Consultant-generated RGA stream assessments were conducted in 1997 for phase I watersheds, and RGA for Onion Creek was conducted in 2002. EII data for physical habitat and Pfankuch channel assessment from 1996 and 1997 were used as independent variables.

To generate an input dataset with a minimum amount of variation and manipulation of the EII physical habitat data, only reaches with a one-to-one relationship between SI scores and EII sites were considered (Method 1). If no EII site fell within the boundaries of a specific reach, the SI score for that reach was not considered. If multiple EII sites fell within a specific reach, then the SI score for that reach would be joined to both sets of EII data. Method 1 generated 59 complete observations.

To generate an input dataset with a maximum number of data points, spatially-averaged EII scores were used for every SI score value (Method 2). If no EII site fell within the boundaries of a specific reach, the SI score for that reach would be joined to the nearest downstream EII site. If multiple EII sites fell within the reach, then the EII data would be averaged for the reach. Method 2 generated 132 complete observations.

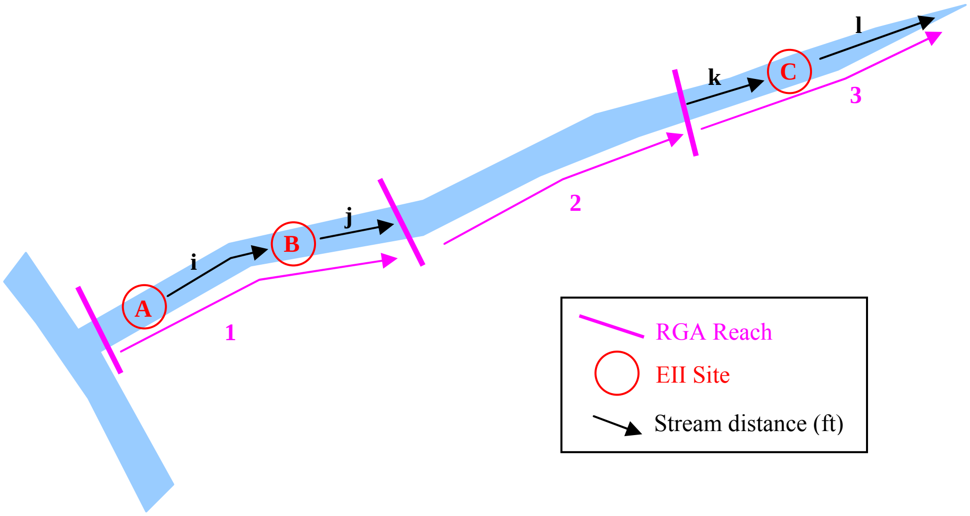

Figure 2. Example of assignment of SI scores to EII data by two different methods.

Table 3. Example assignment of EII data to RGA reach.

Method 1 (One-to-One)		Method 2 (Spatial-average)	
RGA Reach	**EII Sites**	**RGA Reach**	**EII Sites**
1	A	1	(iA+jB)/(i+j)
1	B	2	B
3	C	3	(kB+lC)/(k+l)

Physical habitat and Pfankuch channel assessment variables (Table 1) were included in multiple linear regression and logistic regression models for SI as independent variables along with 9 additional variables (Table 4) including a quantized variable to describe the watershed type (0=non-urban,1=urban) and channel type (0=alluvial channel, 1=rock bed channel, 2=rock control channel, 3=structural channel) from RGA assessments (Chan & Associates 1997).

Table 4. Independent variables included in SI model in addition to physical habitat and Pfankuch channel assessment variables.

Additional independent variables
Cumulative drainage area (acres)
Current impervious cover (%)
Future impervious cover (%)
Watershed type (0=non-urban, 1=urban)
Channel type (0=Al, 1=RB, 2=RC, 3=SC)

The multiple linear regression model was evaluated in SAS (version 9.1) using the REG procedure, with a stepwise model selection option so that independent variables are added singly if the F statistic is significant at ≤ 0.30 level. After a variable is added, all other variables already included in the model are re-evaluated and removed if the F statistic is not significant at the ≤ 0.10 level. Durbin-Watson d statistic results were computed to assess autocorrelation (Durbin and Watson 1951). Durbin-Watson d values close to 2 suggests no autocorrelation of errors (SAS 2004). Multicollinearity of independent variables was assessed using condition index values (Belsey et al 1980) and variance inflation factors. Eigenvalues with high condition indices (10-100) and two or more variables yielding a variance proportion > 0.50 were considered collinear (SAS 2004). Collinear variables were removed and models re-estimated. A plot of residuals versus predicted values were examined for the absence of any marked trends to verify model fit and insure model homoscedasticity. Numerical SI values were used as the dependent variable.

Logistic regression was performed in SAS (version 9.1) using the LOGISTIC procedure. Stepwise, forward, backward and full model selection methods were compared. The logistic regression is useful in modeling ordinal data (SAS 2004). Stability classes were used as the dependent variable.

Model estimates were then tested against Onion Creek RGA data collected in 2002. The most recent complete set of EII physical habitat and channel assessment data per site (with data ranging from 1997 to 2003) was input to the regression models, and predicted values were compared to consultant-generated SI scores from 2002.

Results

Linear regression of each independent variable on SI scores indicate that only 7 of 24 independent variables yield statistically significant univariate linear regression (embeddedness, flow_status, rock_angularity, obstructions, mass_wasting, bottom_size_distribution, bank_rock_content), with weak r^2 values (maximum r^2 value = 0.07). Examination of univariate plots of independent variables versus SI scores reveal no strong linear (or clearly non-linear) relationships, and highlight the ordinal nature of the data.

Multiple Linear Regression Results

Method 1 generated a statistically significant multiple linear regression model (Pr>f = 0.0001, r^2=0.60) with 13 independent variables (Table 5). Durbin-Watson d statistic (d=1.688) value suggests no autocorrelation. Condition indices and variance inflation factors indicate that current and future percent impervious cover may be collinear. Removal of future percent impervious cover from the model resolves the collinearity issue and also yields a statistically significant model (Pr>f = 0.0001), although with only 5 significant independent variables and a reduced adjusted r^2 value (r^2=0.45). Again, d-statistic (d=1.560) values suggest no autocorrelation. The modified model yields low condition index values and roughly equivalent variance inflation factors for each variable. Future impervious cover was removed from the model as it is more difficult to estimate than current impervious cover.

Method 2 generated a statistically significant multiple linear regression model (Pr>f=0.0001, r^2=0.45) with 9 independent variables (Table 5). Durbin-Watson d statistic (d=1.9108) value suggests no autocorrelation. Condition indices and variance inflation factors suggest no collinearity.

Table 5. Summary of model output.

			Method 1 Data F = 7.74, df = 58 Pr>f = 0.0001, r^2 = 0.45			Method 2 Data F= 13.03, df = 131 Pr>f = 0.0001, r^2 = 0.45		
		Component	**Estimate**	**StdErr**	**Pr > F**	**Estimate**	**StdErr**	**Pr > F**
		Intercept	0.0878	0.085	0.31	0.8217	0.121	0.00
Additional		Cum Drainage Area	.	.	.	.	.	.
		Future IC	.	.	.	.	.	.
		Current IC	.	.	.	.	.	.
		Wshed Type	0.0711	0.031	0.03	0.1372	0.030	0.00
		Channel Type	-0.0906	0.021	0.00	-0.0964	0.012	0.00
Pfankuch	Bottom	Bottom Size Dist.	.	.	.	.	.	.
		Brightness	.	.	.	.	.	.
		Clinging Aquatic Veg.	.	.	.	-0.0408	0.014	0.01
		Consolidation	.	.	.	.	.	.
		Rock Angularity	0.0277	0.014	0.05	.	.	.
		Scoring	.	.	.	.	.	.
	Lower Banks	Bank Rock Content	0.0228	0.009	0.01	.	.	.
		Cutting	.	.	.	-0.0217	0.005	0.00
		Entrenchment	.	.	.	.	.	.
		Deposition	.	.	.	.	.	.
		Obstructions	.	.	.	.	.	.
	Upper Banks	Bank Protection from Veg.	.	.	.	.	.	.
		Debris Jam Potential	.	.	.	.	.	.
		Landform Slope	.	.	.	.	.	.
		Mass Wasting	.	.	.	-0.0096	0.006	0.10
Physical habitat	Instream	Frequency of Riffle	.	.	.	.	.	.
		Instream Cover	.	.	.	0.0050	0.003	0.07
		Bank Condition	.	.	.	-0.0152	0.005	0.00
		Channel Alteration	.	.	.	-0.0083	0.003	0.00
		Embeddedness	.	.	.	.	.	.
		Sediment Deposition	0.0082	0.003	0.01	.	.	.
	Riparian Zone	Bank Vegetative Protection	.	.	.	.	.	.
		Riparian Veg. Zone Width	.	.	.	0.0074	0.002	0.00
	Flow	Flow Status	.	.	.	.	.	.

Only watershed and channel type were statistically significant in both models using data from both methods. Following removal of future impervious cover from the full multiple linear regression model using method 1 data to avoid collinearity, neither current or future impervious cover remained as statistically significant independent variables, and 14 physical habitat and Pfankuch variables did not appear in either model. Coefficient of variation estimates from the multiple linear regression model generated using method 1 data are lower (CV=0.2436) than the model generated from method 2 data (CV=0.3172), although adjusted r^2 values are comparable ($r^2 \approx 0.45$).

Assessment of multiple linear regression model output using 2002 Onion Creek RGA data indicate poor agreement for the Onion Creek watershed (Table 6), so that only 1 of 12 predictions placed the reach in correct stability class. Onion Creek is substantially larger than all other watersheds in the greater Austin area, and effects correlated with drainage area may bias model output.

Table 6. Output on Onion Creek RGA data as multiple linear regression validation.

RGA Data			**EII Data & Model Predictions**				
Geomorphic Reach	**SI**	**Class**	**Site #**	**Method 1**		**Method 2**	
				SI^	**Class**	**SI^**	**Class**
ONI-1	0.44	IA	883	0.37	TRAN	0.32	TRAN
ONI-1	0.44	IA	1366	0.43	IA	-0.04	STA
ONI-3	0.49	IA	255	0.30	TRAN	0.32	TRAN
ONI-8	0.59	IA	220	0.21	TRAN	0.20	STA
ONI-9	0.51	IA	239	0.25	TRAN	0.34	TRAN
ONI-10	0.43	IA	236	0.34	TRAN	0.37	TRAN

The multiple linear regression models were applied to the original data, and again there was poor categorization into correct stability class (Table 7). Output model equations were less likely to correct categorize stable and in-adjustment reaches.

Table 7. Application of multiple linear regression equations to input data.

Stability Class	**# Cases**	**% Correct**	
		Method 1 Input	**Method 2 Input**
STA	7	28.6	28.6
TRAN	34	79.4	81.8
IA	22	42.9	45.5
Total	62	66.1	62.9

Adjusted r^2 values decrease if all independent variables are input to the regression equation (equivalent to the original full model), even if the order of independent variables in the full model statement is varied. Use of a quantized stability class variable as the dependent variable in the multiple linear regression models did not improve categorization accuracy.

Logistic Regression Analysis

Logistic regression using method 1 input data yielded the highest percentage of concordant pairs (matching observed SI class and predicted SI class values) for the full model versus any subset of independent variables (Table 8). Using all independent variables, there was no difference in number of concordant pairs when the order of the independent variables was varied. The STA classification was never predicted (correctly or incorrectly). In an attempt to disproportionately represent the STA class during model calibration, 13 TRAN reaches were removed from the calibration data set (Table 9) and the logistic regression was repeated for the full model. This resulted in non-convergence and inaccurate model parameter estimation, and did not improve stability classification accuracy. Application of both (all data and reduced data set) logistic regression model outputs to Onion Creek 2002 RGA data resulted in 5 of the 6 reaches incorrectly classified as TRAN (correct = IA for all reaches). There are not enough STA reaches in the method 1 input data set to accurately predict STA.

Logistic regression model using method 2 input data resulted in a smaller percentage of concordant pairs than the logistic regression model using method 1 input data (Table 8). Again, the full model selection method performed more accurately than the stepwise, forward or backward, and no change was found in prediction accuracy when the order of independent variables in the logistic regression model was varied (for the full model). The STA classification was never predicted by the logistic regression model using method 2 input data (either correctly or incorrectly). In an attempt to disproportionately represent the STA class during model calibration, 42 records from each category were removed and used for validation (Table 9). The reduced method 2 data set resulted in model convergence, but did not improve the percentage of concordant pairs (42%). When applied to the Onion Creek 2002 data, only 2 of the 6 reaches were correctly identified as IA (all other reaches were incorrectly classified as TRAN) for models generated from both the total method 2 input data set and the reduced data set.

Table 8. Percentage of correctly predicted stability classes by logistic regression model selection method.

Model Selection Method	% Correct Classification	
	Method 1 Input	Method 2 Input
Full (None)	76	61
Forward	69	54
Stepwise	61	54
Backward	61	60

Table 9. Proportion of data used for calibration (with remaining data used for model verification) by stability classification for logistic regression.

Stability Class	Method 1		Method 2	
	Total	# used for calibration	Total	# used for calibration
IA	20	15	37	30
STA	61	4	26	20
TRAN	33	15	69	40

Conclusions

No clearly evident univariate relationships exist between SI scores and the EII physical integrity variables. Multiple linear regression does not yield any linear combination of EII physical integrity variables that can reliably predict SI values for use in estimating SI values in stream reaches with no available RGA field data.. Logistic regression models yielded a higher percentage of correct classifications than multiple linear regression analysis most likely due to the ordinal nature of the EII physical integrity data, but are still unreliable for prediction.

Stream reaches in the “stable” category are never predicted by logistic regression models and were more frequently categorized incorrectly by multiple linear regression models. Stable stream reaches represented a smaller proportion of both method 1 and method 2 input data sets than either in adjustment or transitional reaches. Attempts to correct this by removal of IA and TRAN stream reaches during model calibration did not improve prediction accuracy. Additional RGA data on STA reaches may be necessary to properly calibrate models.

Neither logistic nor multiple linear regression methods accurately predicted stability classes for Onion stream reaches. The Onion Creek watershed is larger than any other stream watershed in the greater Austin area (and larger than any stream reach used to calibrate the model), and effects relating to drainage area size that are unaccounted for by EII physical integrity data (and not accounted for using cumulative drainage area as an independent variable) may bias model outputs.

There were no substantial differences in model output accuracy for the multiple linear regression using either method 1 or method 2 input data. Method 1 data, despite a reduced number of data points, did yield more accurate classification in logistic regression models than method 2 data most likely due to a reduction in variance.

A more accurate model input data set with reduced variability could be generated by re-visiting the original RGA transect locations and visually observing the Pfankuch and EPA habitat parameters, then repeating this analysis.

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