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LAND USE AND WATER QUALITY IN A RURAL CLOUD FOREST REGION (INTAG, ECUADOR)

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ABSTRACT

The Intag cloud forest region of northwestern Ecuador is characterized by exceptional biodiversity, large known and unknown deposits of copper and other valuable minerals, and a high level of environmental awareness and concern among the human population. Its 1000 km of rivers and streams are essential for household use, crop irrigation, livestock production and sustaining unique ecosystems. However, no published data exist on water quality in the region. This study characterizes water quality in five river systems in Intag and relates it to land use (protected forest, agriculture/pasture, urban development or mining) upstream of the sampling point. Additionally, we sampled 15 community water supply systems. Parameters measured included turbidity, temperature, dissolved oxygen, pH, faecal indicator bacteria (FIB), nitrate, phosphate, ammonium, Ni, Mn, Cu, Zn, Cd, Pb, As, Cr, discharge and aquatic invertebrate diversity. Significant differences in pH, aquatic invertebrate diversity, and the concentrations of FIB, nutrients and dissolved metals were observed between land use groups. Forested streams consistently had the lowest pollutant concentrations, whereas those flowing past population centres or mining areas showed the greatest impairment. Elevated As concentrations were observed in association with abandoned mining boreholes, hot springs and wastewater discharges. FIB, nutrient and metal concentrations in water systems were similar to those in forested streams, indicating that these systems maintain water in an unpolluted condition. To preserve and enhance Intag's generally good water quality, we recommend installing wastewater treatment systems in larger towns and approaching all mining activity, including exploration, with extreme caution.

KEY WORDS: Ecuador; water quality; land use; cloud forest; mining; arsenic; streams; faecal indicator bacteria

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INTRODUCTION

The Intag cloud forest region, which consists of six parishes (Apuela, Cuellaje, García Moreno, Peñaherrera, Plaza Gutiérrez and Vacas Galindo) in Cotacachi Canton and one parish (Selva Alegre) in Otavalo Canton, is located in Imbabura province in northwestern Ecuador between 0.2345 and 0.4277°N (Figure 1). Its elevation ranges from 500 to 2500 m above sea level. It has a land area of 1489 km^2 and a population of approximately 15 000, who live on farms or in small towns of up to 1000 people. Human alteration of the landscape is limited: 62.8% of the land area in Intag's seven parishes is completely forested, 15.3% is partially forested and 12.9% is devoted to agriculture or pasture. The remaining 9.0% is occupied by other natural cover, including shrubland, water bodies and páramo, or tropical alpine grassland (SIGAGRO, 2010).

Three of Intag's defining characteristics are its exceptional biodiversity, its subsoil mineral resources, and its high level of community organization, environmental activism and conservation. Intag is part of the Tropical Andes Bioregion, a biodiversity hotspot with endemic plants and vertebrates comprising 2% of total species worldwide (Myers *et al*., 2000). Endemic to the Tropical Andes are 20 000 species of plants, 68 species of mammals, 677 species of birds, 218 species of reptiles and 604 species of amphibians (Brooks *et al*., 2002).

The western flanks of the Andes are also a subduction zone rich in porphyritic copper deposits. In addition to copper, these deposits contain other economically valuable elements including molybdenum, gold and silver. Intag's one known deposit, Junín, consists of an estimated 319 million metric tons (MT) of ore containing 0.71 g MT^{-1} Cu and 0.026 g MT^{-1} Mo (Singer *et al*., 2005). The tract in which Intag is located (SA05PC) covers 58 797 km^2 in Panama, Colombia and Ecuador and is estimated to contain 1.6–16 billion MT of ore, with about 75% of the deposits undiscovered (Cunningham *et al*., 2008).

Since the early 1990s, Intag's known and unknown mineral resources have attracted the interest of mining companies. Between 1991 and 1995, Mitsubishi subsidiary Bishimetals drilled 24 mining boreholes in the vicinity of

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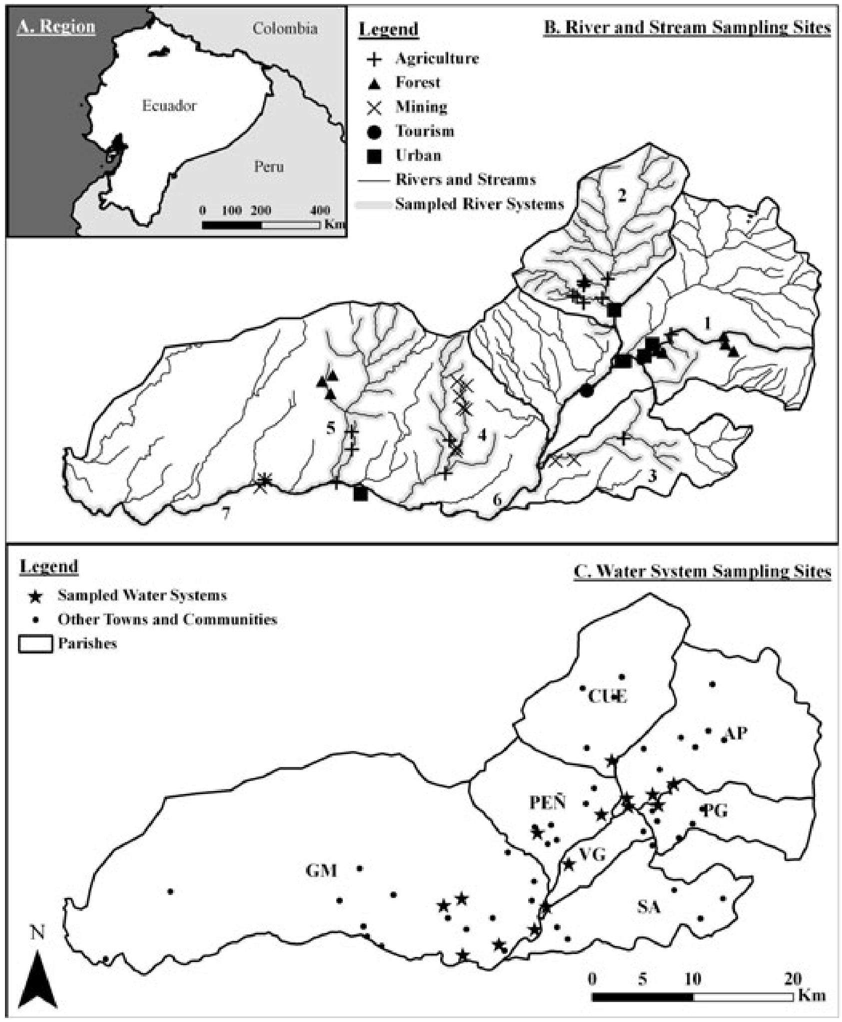

Figure 1. Map of the study area. In panel A, the shaded black area indicates the seven parishes of Intag, which are shown in detail in panels B and C. In panel B, numbers indicate river systems: 1—Toabunchi, 2—Cristopamba, 3—Quinde, 4—Junín/Chalguayacu, 5—Magdalena/Verde, 6—Íntag and 7—Guayllabamba. In panel C, parishes are abbreviated as follows: Apuela (AP), Cuellaje (CUE), García Moreno (GM), Peñaherrera (PEÑ), Plaza Gutiérrez (PG), Selva Alegre (SA) and Vacas Galindo (VG)

Junín. These boreholes were later abandoned because of community resistance. Most have been overgrown by the forest and can no longer be located (Holmes, 2008). Later, Canadian Ascendant and Chilean Codelco initiated exploratory activities but neither drilled boreholes. At present, only a single small gold mine, located near the town of El Corazón in García Moreno parish, is operating. However, pressure to develop the area's mineral resources will likely continue in the future because of the high prices of copper (Bova, 2012) and gold (Baur and McDermott, 2010), which have more than doubled in value over the past decade. Limestone deposits also exist in the area, and two limestone quarries are active in Selva Alegre Parish.

Spurred by the threat of open-pit copper mining, Intag's population has developed an exceptional level of community organization and concern about the environment. In 2000, Cotacachi, in which six of Intag's seven parishes are located, declared itself a 'cantón ecológico' or 'environmental canton', and the municipal government has taken an active role in opposing mining and promoting sustainable development. As of 2012, the local grassroots environmental organization Defensa y Conservación Ecológica de Íntag (Intag Defense and Ecological Conservation; Spanish acronym, DECOIN) and international NGO Rainforest Concern have helped establish 41 community-owned and managed watershed reserves serving parish seats and smaller communities in the region (DECOIN, 2012). Some reserves are primary forest, whereas others were reforested after being purchased. Residential development, agriculture and cattle are prohibited within the reserves. In addition to the watershed reserves, the region contains 21 other public and private forest reserves (Carlos Zorrilla, personal communication). Many organizations

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devoted to sustainable economic development are active in Intag, including an organic coffee growers' association, an ecotourism consortium and several women's groups producing hats, bags, soaps, jewellery and other products.

Intag's water resources consist of approximately 1000 km of rivers and streams, upland springs feeding the streams, and hot springs located in Nangulví (Peñaherrera parish). The rivers and streams drain either into the Intag River, a large tributary of the Guayllabamba, or into the Guayllabamba directly (Figure 1). None of these rivers and streams is gauged. Most residents obtain drinking water from simple collection and distribution systems, in which water is piped from upland springs or small creeks into tanks and then to individual taps. Residents living outside communities with water systems often pipe water to their homes from a nearby spring. Some tanks are designed to allow sediment to settle out of the water prior to distribution and some include filtration through sand and/or gravel. One system, serving the Cuellaje parish seat, includes both filtration and chlorination. In the dry summer season, it is common for personal and community water systems to run dry, forcing people to use rivers for drinking, cooking and bathing.

Previous studies conducted in alpine and cloud forest streams in Central and South America have revealed correlations between land use and water quality. In particular, mining activity has been associated with lower pH (Appleton *et al.*, 2004; Loayza-Muro *et al.*, 2010), elevated concentrations of dissolved metals including As, Cu, Cd, Pb and Zn (Tarras-Wahlberg *et al.*, 2001; Appleton *et al.*, 2004; Loayza-Muro *et al.*, 2010), and reduced diversity of aquatic invertebrates (Tarras-Wahlberg *et al.*, 2001). In addition, human settlement combined with inadequate sanitation has been associated with elevated concentrations of faecal indicator bacteria (FIB) and incidence of gastrointestinal disease elsewhere in Ecuador (Levy *et al.*, 2009).

Maintaining good water quality is essential for the conservation of Intag's biodiversity, the health of its human residents, and the accurate assessment of environmental impacts that may occur in the future. However, no data on water quality in the region have been published. To address this gap, this study aimed to (1) characterize the quantity (discharge) and quality (pH, turbidity, aquatic invertebrate diversity and concentrations of dissolved oxygen, FIB, nutrients and metals) of water in rivers, streams and water systems in Intag, and (2) explore the relationship between land use and water quality.

METHODS

Site selection and classification

We sampled 50 river and stream sites in five river systems: Cristopamba (Cuellaje Parish), Toabunchi (Apuela and Plaza Gutiérrez Parishes), Quinde (Selva Alegre Parish), Junín/Chalguayacu (García Moreno Parish) and Magdalena/Verde (García Moreno Parish) (Figure 1). These sites were chosen to represent the range of land uses that exist in Intag. Additionally, we sampled 15 parish seat and community water systems, an abandoned mining borehole, and wastewater effluent discharging from the Nangulví Ecotourism Complex, which contains natural hot springs. Borehole and effluent samples are included with river and stream samples for the remainder of this paper because they were sampled immediately prior to flowing into a river or stream. The majority (28) of the river and stream sites were sampled twice, once between August 2010 and October 2010 (dry season), and once between November 2010 and February 2011 (rainy season). Two sites were sampled three times, and the remaining sites were sampled once. The majority of water systems were sampled once (Appendix 1).

The sites were classified as follows. Sites immediately (<1 km) downstream of a town or a town's wastewater discharge pipe were classified as urban. Sites downstream of a mine, quarry or borehole were classified as mining. Mining sites in the Junín River system (JUN1–8) were located near abandoned exploratory boreholes; those in the Verde River system (RV1–2) were located downstream of the El Corazón gold mine; and those in the Quinde River system (QLL1 and RQ3) were located downstream of limestone quarries. Sites within a protected forest or reserve were classified as forested. The two Nangulví samples were classified as tourism. The remaining sites were classified as agriculture/pasture. The presence of crops and/or cattle was confirmed visually during each sampling event. Because crops and cattle are usually raised in close proximity to each other, it was not feasible to separate these two land uses in this study.

Of the 50 sites, 21 were classified as agricultural, 9 as forested, 11 as mining, 7 as urbanized and 2 as tourism. We note that several sites within the Junín watershed initially classified as forested (JUN4, 5 and 7), agricultural (JUN1) or urbanized (JUN2) showed signs of impact from abandoned mining boreholes and that these sites were reclassified as mining.

Geographic analysis

The geographic coordinates of each sampling site were recorded in the field using a Garmin GPSmap 76 (Garmin, Olathe, Kansas, USA) hand-held unit. When it was not possible to record coordinates in the field, usually because of heavy forest cover, the location was estimated based on field notes and nearby landmarks such as rivers, roads and towns. Contour maps (1:25 000 and 1:50 000 scale) of the region were obtained from the Instituto Geográfico Militar (Quito, Ecuador). Geographic data about rivers, streams, political boundaries, location of towns and population density were obtained from the Secretaría Nacional de Planificación y Desarrollo (Ecuadorian National Secretary of Planning and

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Development) and the Universidad San Francisco de Quito. Land use data were obtained from the Sistema de Información Geográfica y Agropecuaria (Geographic and Agricultural Information System; Spanish acronym, SIGAGRO), an Ecuadorian national government agency. The SIGAGRO data set was not used for site classification because it did not include small towns or mines. Geographic analysis was performed, and maps were created, using ArcMap 9.3.1 (ESRI) (ESRI, Redlands, California, USA).

Field measurements (turbidity, temperature, dissolved oxygen and pH)

Water turbidity, temperature, dissolved oxygen concentration and pH were measured in the field. Turbidity was assessed by measuring the Secchi depth with a 100-cm long transparency tube (Forestry Suppliers, Inc., Jackson, Mississippi, USA). If the disc was still visible at the bottom of the tube, a Secchi depth of >100 cm was recorded. The transparency tube was only used during bright daylight hours (09:00–16:00). Temperature and dissolved oxygen concentration were measured using a YSI DO200 hand-held probe (YSI, Yellow Springs, OH, USA). The dissolved oxygen metre was damaged from 23 August to 12 October 2010, so no dissolved oxygen measurements could be collected during that period. pH was measured using colorpHast indicator strips (EMD Chemicals, Inc.; 2.0–9.0 range, Quincy, Massachusetts, US), following the directions on the package.

Faecal indicator bacteria

The concentrations of total coliform (TC) and *Escherichia coli* (EC) were measured using Coliscan Easygel kits (Micrology Labs, Goshen, Indiana, USA) following the manufacturer's instructions. Between 1 and 5 mL of sample water was used per test, and samples were incubated at room temperature for 48 h. Colisan Easygel kits were chosen because they do not require filtration or incubation above room temperature, so they can be used easily in remote field locations without consistent access to electricity. They are approved by the US Environmental Protection Agency (EPA) for water quality monitoring in some states and are generally accurate in predicting whether a sample falls above or below the EPA recreational standard of 235 CFU 100 mL^{-1} (Stepenuck *et al*., 2011). The lower and upper limits of detection for this method were 1 and approximately 300 CFU in the sample volume, respectively. For the purpose of statistical calculations, samples with FIB concentrations below the lower detection limit were assigned a concentration of one-half the detection limit (0.5 CFU in the sample volume), and samples with FIB concentrations above the upper detection limit were assigned a concentration equal to that limit (300 CFU in the sample volume). Six blanks and five duplicate samples were run during the course of the study.

Nutrients

Samples for nutrient (nitrate, ammonium and phosphate) analysis were filtered in the field with a 0.2 μm filter, acidified to pH 2 with hydrochloric acid (J.T. Baker, Phillipsburg, NJ, USA) on the day of collection to preserve them and later analyzed at the Smithsonian Environmental Research Center (Edgewater, MD, USA). Nitrate (NO_3^-) concentrations were measured as described by Jordan *et al*. (2003). Ammonium (NH_4^+) and phosphate (PO_4^3) concentrations were measured as described by Hartzell and Jordan (2012).

Dissolved metals

Concentrations of nickel (Ni), manganese (Mn), copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb), arsenic (As) and chromium (Cr) were measured. Water samples for metal analysis were filtered in the field with a 0.2 μm filter and acidified to pH 2 with ultrapure nitric acid (J.T. Baker) later the same day. Metal concentrations were analyzed on an inductively coupled plasma mass spectrometer at the Smithsonian Environmental Research Center. Percent recoveries, based on NIST standard runs, were 98% for Ni and Mn, 96% for Cu, 109% for Zn, 90% for Cd, 90% for Pb, 102% for As and 104% for Cr. Detection limits (estimated as three times the metal concentrations measured in a field blank sample; ng L^{-1}) were as follows: 1.3 for Ni, 1.8 for Mn, 4.6 for Cu, 24 for Zn, 0.3 for Cd, 0.4 for Pb, 0.4 for As and 0.8 for Cr.

Discharge

Stream discharge was estimated using a standard velocity–area method (Gordon *et al*., 1992). At most sites, depth and velocity were measured at 10 equally spaced points across the stream width. When possible, this procedure was repeated 2–3 times at the same site. The standard deviation within 31 groups of replicate measurements, expressed as a percentage of the mean, ranged from 1% to 63% with an average value of 21%. Discharges for springs and water systems were calculated by measuring the amount of time to fill a container of known volume and represent the average of 3–5 individual trials.

In some cases ($n = 22$), it was impossible to measure depth and velocity across the stream width because either (1) the stream could not be safely crossed on foot, nor could these parameters be measured from a bridge, or (2) the velocity metre was not functioning, and the discharge was roughly estimated as follows. The width of the stream was either measured or estimated, the average depth was estimated either visually or as the average of several representative point measurements, and the average velocity was estimated either as the average of several measurements made either with the velocity metre or using a drifter. These

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estimated stream discharges are indicated with asterisks (*) in the Appendix. Additionally, we note that all discharge measurements reported in this study represent instantaneous discharges at specific moments in time and may not be representative for annual fluxes.

Aquatic invertebrates

The diversity of aquatic invertebrates was assessed qualitatively by collecting them with a hand net for a 2-min period at each site, attempting to sample all types of habitat that were present. Characteristics defining different habitat types included sunshine or shade, water depth and velocity, and substrate type. The material collected with the hand net was placed in a clear, screw-top plastic jar. Within 8 h, the contents were emptied into a white tray, and all invertebrates visible to the naked eye were removed with tweezers and preserved in ethanol. They were later identified to family at the Universidad San Francisco de Quito's Aquatic Ecology Lab under a stereoscope, using a key or field guide when necessary.

The Biological Monitoring Work Party method for Colombia (BMWP/Col) was used to calculate an index of water quality based on aquatic macroinvertebrate diversity. This method assigns a point value of 1–10 to each family based on its sensitivity to environmental pollution and degradation, with one being the most resistant and 10 the most sensitive. If at least one individual from a given family is present in a sample, the sample earns points for that family. Then, the points from all the families present in the sample are added up to obtain the index, which can vary from 0 to greater than 100. Based on the index, the site's water quality is classified as excellent, good, fair, poor, critical or highly critical (Roldán Pérez, 2003; Table 1). Family richness for each site was also calculated.

Statistical methods

Statistical analyses were performed in Microsoft Excel 2007 and R version 2.15.1. The statistical significance of differences in means among sample groups was assessed using a one-way ANOVA followed by a Tukey multiple comparisons of means test if the ANOVA revealed significant variation between groups. Differences were deemed significant if the *p*-value was less than 0.05. Correlations between variables were investigated by calculating the Spearman non-parametric correlation coefficient. Correlations were deemed significant if the *p*-value was less than 0.01; a more stringent significance criterion was used because of the large number of potential correlations investigated. pH values were converted to H^+ ion activity prior to performing statistical calculations, and concentrations of FIB were log-transformed before performing statistical analysis because their range spanned more than three orders of magnitude, and the measurements were not normally distributed.

Table I. Point values for different aquatic invertebrate families and criteria for water quality characterization under the Biological Work Monitoring Party – Colombia (BMWP/Col) method

Family	Point value
Anomalopsychidae, Atriplectidae, Blepharoceridae, Calamoceratidae, Ptilodactylidae, Chordodidae, Gomphidae, Hydridae, Lampyridae, Lymnessiidae, Odontoceridae, Oligoneuriidae, Perlidae, Polythoridae, Psephenidae	10
Ampullariidae, Dystiscidae, Ephemeridae, Euthyplocidae, Gyrinidae, Hydraenidae, Hydrobiosidae, Leptophlebidae, Philopotamidae, Polycentropodidae, Polymitarcydae, Xiphocentronidae	9
Gerridae, Hebridae, Helicopsychidae, Hydrobiidae, Leptoceridae, Lestidae, Palaemonidae, Pleidae, Psuedothelpusidae, Saldidae, Simuliidae, Veliidae	8
Baetidae, Caenidae, Calopterigidae, Coenagrionidae, Corixidae, Dixidae, Dryopidae, Glossosomatidae, Hyallelidae, Hydroptilidae, Hydropsychidae, Leptohyphidae, Naucoridae, Notonectidae, Planariidae, Psychodidae, Sciritidae	7
Aeshnidae, Ancylidae, Corydalidae,Elmidae, Libellulidae, Limnichidae, Lutrochidae, Megapodagrionidae, Sialidae, Staphylinidae	6
Belostomatidae, Gelastocoridae, Mesoveliidae, Nepidae, Planorbiidae, Pyralidae, Tabanidae, Thiaridae	5
Chrysomelidae, Stratiomyidae, Haliplidae, Empididae, Dolichopodidae, Sphaeridae, Lymnaeidae, Hydrometridae, Noteridae	4
Ceratopogonidae, Glossiphoniidae, Cyclobdellidae, Hydrophilidae, Physidae, Tipulidae	3
Culicidae, Chironomidae, Muscidae, Sciomyzidae, Syrphidae	2
Tubificidae	1
Water quality rating	
Excellent	>150
Good	101–150
Fair	61–100
Poor	36–60
Critical	16–35
Highly critical	<15

Adapted from Roldán Pérez (2003).

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RESULTS

Turbidity

In general, the water in Intag's rivers, streams and water systems was quite clear (Table 2). Of the 114 Secchi depth measurements that were made, only 17 were less than 100 cm: three were from agricultural sites, two were from forested sites, five were from mining sites and four were from water systems. The mean Secchi depth did not vary significantly between land use groups [$F(4, 74) = 1.068$; $p = 0.409$].

Dissolved oxygen

Only four out of 66 dissolved oxygen measurements were lower than 5 mg L^{-1}. These four low-oxygen samples were as follows: water emerging from an abandoned mining borehole (JUN8; 0.3 mg L^{-1}), effluents from the Nangulví Ecotourism Complex (NAN1 and NAN2; 1.5 and 5.0 mg L^{-1}, respectively) and a creek receiving untreated sewage from the community of Pucará (PUC4; 4.3 mg L^{-1}). We note that some samples are missing dissolved oxygen measurements because the oxygen metre was being repaired from 23 August to 12 October 2010. All other samples had dissolved oxygen concentrations between 6.2 and 12.6 mg L^{-1}, sufficient to support most aquatic life ((USEPA), 1986; Table 2). Differences in mean dissolved oxygen concentration between land use groups were not significant [$F(4, 54) = 0.576$; $p = 0.681$].

pH

All samples had relatively neutral pH values of between 5 and 8 (Table 2). pH values measured in this study were similar to those reported in other Central and South American cloud forest streams (McDowell and Asbury, 1994; Von Ellenrieder, 2007; Boy *et al*., 2008; Loayza-Muro *et al*., 2010) but higher than those at mining sites in the Peruvian Andes (3.4–4.2; Loayza-Muro *et al*., 2010). Variation in the concentration of H^+ ions between land use groups was statistically significant [$F(4, 77) = 7.929$; $p = 2 \times 10^{-5}$]. Mining sites were significantly more acidic than water system samples ($p = 0.002$) and forested sites ($p = 0.04$), and agricultural sites were also more acidic than water systems ($p = 0.0004$). We note that the method used to measure pH was imprecise, with an uncertainty of 0.5 to 1 pH unit.

Total coliform and E. coli

Total coliform concentrations in streams were generally high and did not appear to be strongly related to human impacts on the landscape (Table 3); however, significant differences in the logarithmic mean TC concentration between land use groups were observed [$F(4, 127) = 6.185$; $p = 0.00014$]. Log TC concentrations were significantly lower in water system samples than in agricultural, forested or urban stream sites ($p < 0.05$). Two effluent samples from the Nangulví Ecotourism Complex had high TC concentrations (Table 3).

In contrast, the significant between-groups variability in EC concentrations [$F(4, 126) = 9.647$; $p = 8 \times 10^{-7}$] did appear to be related to human activity (Table 3). Urban sites had significantly higher log EC concentrations than forested or mining sites, and both agricultural and urban sites had significantly higher log EC concentrations than did water systems ($p < 0.05$). Water system samples in Intag had lower EC concentrations than drinking water samples from northern coastal Ecuador (Levy *et al*., 2009). One effluent

Table III. Average (± standard deviation) log total coliform (TC) and *E. coli* (EC) concentrations by land use group

Land use	n	Log TC (CFU 100 mL^{-1})	Log EC (CFU 100 mL^{-1})
FOR	9	3.15 ± 0.62	1.21 ± 0.23
AG	21	3.02 ± 0.75	1.64 ± 0.68
URB	7	3.49 ± 0.52	2.06 ± 1.01
MIN	11	2.51 ± 0.74	1.29 ± 0.31
TUR	2	3.18–3.90	1.60–3.48
WS	85	2.40 ± 0.82	1.18 ± 0.32

CFU, colony-forming unit. Land use class abbreviations as in Table 2.

Table II. Average (± standard deviation) Secchi depth, H^+ activity, dissolved oxygen concentration and discharge for agricultural (AG), forested (FOR), mining (MIN), urban (URB) and water system (WS) sites

Land use	n	Secchi depth (cm)	H^+ activity ($\times 10^{-6}$)	Dissolved oxygen (%)	Discharge ($m^3 s^{-1}$)
FOR	9	94 ± 14	1.84 ± 1.88	83 ± 6	0.69 ± 0.82
AG	21	94 ± 18	4.38 ± 4.06	87 ± 6	2.29 ± 4.22
URB	7	78 ± 35	2.32 ± 1.58	78 ± 19	3.19 ± 3.00
MIN	11	89 ± 18	5.55 ± 4.19	83 ± 28	1.76 ± 3.38
TUR	2	100	0.018–0.032	21–65	–
WS	31	93 ± 19	0.88 ± 1.77	84 ± 16	0.0019 ± 0.0017

Tourism (TUR) sites have a range rather than average ± standard deviation because only two sites were sampled.

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sample from the Nangulví Ecotourism Complex (NAN1) had a very high EC concentration, whereas the other effluent sample (NAN2) was relatively low.

Nutrients

Apart from the two effluent samples from the Nangulví Ecotourism Complex, phosphate concentrations were generally low. Although the ANOVA indicated significant variability between groups [$F(4, 75) = 2.57$; $p = 0.0447$], differences between group means were not significant according to the Tukey test. The range of phosphate concentrations was similar to that observed in other Central and South American cloud forest streams (0–640 μg PO_4^{3-}-P L^{-1}; McDowell and Asbury, 1994; Boy *et al*., 2008; Encalada *et al*., 2010; Loayza-Muro *et al*., 2010; Bücker *et al*., 2011). Phosphate concentrations in effluent samples from the Nangulví Ecotourism Complex were considerably higher than those measured in other land use categories or water system samples (Table 4). High concentrations were also measured in water emerging from the mining borehole in Junín (JUN8; 204 μg L^{-1}) and in the Guayllabamba River near the community of El Chontal (RG1; 270 μg L^{-1}).

With a few exceptions, ammonium concentrations were low; however, significant differences were observed between land use groups [$F(4, 76) = 2.803$; $p = 0.0315$]. Urban sites had significantly higher ammonium concentrations than forested, agricultural, mining or water system samples ($p < 0.05$). One sample from the Nangulví Ecotourism Complex had very high ammonium (NAN1; 2231 μg L^{-1}). The other (NAN2; 243 μg L^{-1}) was almost 10 times lower, although still higher than most other samples. Other samples with high ammonium concentrations were effluent from a trout farm in Cuellaje Parish (CUE7C; 128 μg L^{-1}), the Guayllabamba River near El Chontal (RG1; 299 μg L^{-1}), a stream receiving untreated sewage in Pucará (PUC4; 332 μg L^{-1}) and a domestic tap in the community of Santa Rosa de Plaza Gutiérrez (LD2; 306 μg L^{-1}). With the exception of NAN1, ammonium concentrations measured in this study were similar to those reported for other Central and South American cloud forest streams (12–570 μg PO_4^{3-}-P L^{-1}; McDowell and Asbury, 1994; Boy *et al*., 2008; Encalada *et al*., 2010; Loayza-Muro *et al*., 2010: Bücker *et al*., 2011).

Table IV. Average (± standard deviation) nutrient concentrations by land use group

Land use	n	Phosphate-P (μg L^{-1})	Ammonium-N (μg L^{-1})	Nitrate-N (μg L^{-1})
FOR	9	14.5 ± 9.8	25.9 ± 10.9	93.4 ± 59.5
AG	21	17.9 ± 16.9	28.9 ± 25.2	89.3 ± 125
URB	7	55.1 ± 94.5	93.4 ± 110.4	270 ± 537
MIN	11	62.5 ± 90.0	29.0 ± 10.8	201 ± 199
TUR	2	543–610	243–2230	370–430
WS	32	39.4 ± 23.4	38.0 ± 51.3	211 ± 225

Abbreviations as in Table 2.

Nitrate concentrations in all samples were low and similar to those measured in other Central and South American cloud forest streams (20–1100 μg L^{-1} nitrate-N; McDowell and Asbury, 1994; Boy *et al*., 2008; Bücker *et al*., 2011). Except for one sample from the Guayllabamba River (RG1; 1.5 mg NO_3^--N L^{-1}), all samples had concentrations less than 1 mg L^{-1}. No significant differences between land use categories were observed [$F(4, 75) = 1.465$; $p = 0.221$]. Nitrate levels in all samples were well below the EPA drinking water limit of 10 mg L^{-1}, indicating that nitrate pollution does not pose a threat to human health in Intag.

Dissolved metals

The dissolved metals measured in this study can be divided into three groups based on how the concentrations relate to field blank concentrations and EPA drinking water standards. Concentrations of metals in the first group (Cd, Pb and Cr) were less than or similar to field blank concentrations in all field samples, indicating that no detectable quantity of these metals was present.

Concentrations of metals in the second group (Ni, Mn, Cu and Zn) were higher than the field blank at least in some samples (Table 5). Mn, Cu and Zn showed significant variability related to land use category [$F(4, 78) = 3.394$, 8.438 and 2.785, respectively; $p < 0.05$]. Effluent samples from the Nangulví Ecotourism Complex contained 1.0–1.5 μg L^{-1} of Ni, about three times greater than concentrations measured in other samples and the field blank.

Mining sites had significantly higher Mn concentrations than did water systems or agricultural sites ($p < 0.05$). Of mining sites, only certain sites in the Junín River system (JUN5, JUN6 and JUN8) had high Mn (49–442 μg L^{-1}, compared with 0.4–12 μg L^{-1} for other mining samples). NAN1 and NAN2 had relatively high Mn concentrations (156 and 52 μg L^{-1}, respectively), and the field blank had a very low concentration (0.6 μg L^{-1}).

Cu levels were approximately 43 μg L^{-1} higher in samples from mining areas compared with all other land use groups ($p < 0.05$), which had concentrations of 5 μg L^{-1} or lower (Table 5). Despite these significant differences, concentrations in all samples were well below EPA drinking water standards. The high variability in mining samples is because only samples from the Junín River and its tributaries had elevated Cu concentrations, whereas samples from parts of the Quinde and Verde Rivers affected by mining had similar Cu concentrations to non-mining areas. Additionally, two sites in the Junín River system (JUN6 and JUN8) had relatively low Cu concentrations (2.5–8.3 μg L^{-1}), whereas the other sites were considerably higher (32–222 μg L^{-1}).

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Table V. Average (± standard deviation) dissolved metal concentrations by land use group

Land use	n	Mn ($\mu g\,L^{-1}$)	Cu ($\mu g\,L^{-1}$)	Zn ($\mu g\,L^{-1}$)	As ($\mu g\,L^{-1}$)
FOR	9	5.64 ± 10.5	1.50 ± 1.22	6.52 ± 2.40	0.82 ± 0.87
AG	21	3.63 ± 4.07	2.67 ± 2.68	5.50 ± 1.48	0.91 ± 0.99
URB	7	9.09 ± 14.6	1.61 ± 1.17	7.15 ± 6.08	4.69 ± 5.38
MIN	11	58.5 ± 128	44.2 ± 63.0	16.4 ± 16.7	12.3 ± 13.2
MIN (Junín)	7	88.8 ± 156	68.7 ± 68.5	22.0 ± 19.0	18.6 ± 12.8
MIN (Other)	4	5.28 ± 5.49	1.42 ± 0.82	6.76 ± 3.55	1.37 ± 1.10
TUR	2	52.3–156.1	1.70–2.54	5.85–9.09	388–1316
WS	35	1.96 ± 3.42	1.23 ± 0.96	9.42 ± 10.20	0.64 ± 0.66

Mining sites have been divided into those in the Junín watershed and those in other watersheds because metal concentrations were more elevated in the Junín sites. Abbreviations as in Table 2.

Average Zn concentrations were significantly higher in mining sites than in agricultural sites ($p < 0.05$). Again, this difference was driven by high concentrations (up to 79 $\mu g\,L^{-1}$) in some Junín samples, whereas samples from sites in other rivers affected by mining were similar to those in non-mining areas (Table 5).

The third group consists of a single element: As. As concentrations in most samples were higher than that of the field blank (0.1 $\mu g\,L^{-1}$) but lower than the EPA's drinking water standard (10 $\mu g\,L^{-1}$), and significant variability in As concentration was observed between groups [$F(4, 78) = 12.87$; $p = 4.3 \times 10^{-8}$]. As concentrations in mining sites were significantly higher than in any other land use category ($p < 0.05$). Concentrations in NAN1 and NAN2 were 388 and 1316 $\mu g\,L^{-1}$, respectively. As concentrations at nine sites (five mining, two urban and the two Nangulví effluent samples) exceeded 10 $\mu g\,L^{-1}$, indicating a possible health risk if residents were to consume the water.

Considerable variability in As concentration was observed within the urban and mining land use categories. Within the urban category, the Cristopamba River downstream of Cuellaje (CUE8; 0.7 $\mu g\,L^{-1}$) and the stream receiving sewage from Pucará (PUC4 and AP3; 0.2 and 1.0 $\mu g\,L^{-1}$, respectively) were not enriched in As compared with other land uses, whereas the Guayllabamba River (RG1; 12.9 $\mu g\,L^{-1}$) and the Apuela River immediately downstream of a wastewater discharge (AP2; 11.2–12.5 $\mu g\,L^{-1}$) exceeded the EPA standard. Sites in the Junín watershed had high concentrations of As, ranging from 36.5–44.3 $\mu g\,L^{-1}$ at the mining borehole (JUN8) to 5.5–6.4 $\mu g\,L^{-1}$ near the town of Junín (JUN2). Sites downstream of the Corazón gold mine (RV1–2; 0.3–0.8 $\mu g\,L^{-1}$) and the Selva Alegre limestone quarries (RB1, RQ3, QLL1; 1.2–2.7 $\mu g\,L^{-1}$) had much lower As concentrations, comparable with non-mining sites.

In general, dissolved metal concentrations in Intag's streams were similar to those in other Central and South American streams without mining impacts (Smolders *et al.*, 2003; Loayza-Muro *et al.*, 2010). The high Cd, Cu, Pb and Zn concentrations measured in mining regions of southern Ecuador (Tarras-Wahlberg *et al.*, 2001; Appleton *et al.*, 2004), Peru (Loayza-Muro *et al.*, 2010) and Bolivia (Smolders *et al.*, 2003) were not observed in streams in Intag's mining areas, possibly because of the different type and/or lower intensity of mining activity. As levels in the Junín and Nangulví areas were considerably higher than background levels in streams in the Peruvian Andes, but somewhat lower than mining-impacted streams in that area (Loayza-Muro *et al.*, 2010).

Discharge

The rivers and streams included in this study had a very wide range of discharges. Land use categories did not differ significantly in terms of mean discharge. The discharge ranges for each land use category ($m^3\,s^{-1}$) were as follows: agriculture 1.27×10^{-4}–3.38, forest 2.38×10^{-3}–6.73, mining 3.05×10^{-3}–19.3 and urban 3.96×10^{-4}–11.6. With a single exception, the discharges of rivers and streams that were sampled once in the dry season (between August and October 2010) and once in the wet season (between November 2010 and February 2011) were higher during the second sampling period (Appendix). The amount of the increase varied from 28% of the dry season discharge to 30 times greater (3000%).

Aquatic invertebrates

Invertebrates belonging to 11 orders and 49 families were identified at the 35 sites where aquatic invertebrate diversity was assessed. The family-level richness of sites ranged from 2 to 25, and the BMWP/Col index values ranged from 9 to 117 (Table 6). Mean BMWP/Col index values for forested, agricultural, urban and mining sites corresponded to ratings of fair, fair, critical and poor, respectively. We note that it is likely that these index values underestimate the actual diversity of aquatic invertebrates present in the streams because the collection time was only 2 min.

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Table VI. Aquatic invertebrate diversity at sites within each land use

Order	Family	FOR (6)	AG (14)	URB (5)	MIN (10)
Ephemeroptera	Baetidae	6	13	3	7
	Ephemerelidae	0	1	0	0
	Leptohyphidae	6	12	4	3
	Leptophlebiidae	6	12	3	1
	Oligoneuriidae	3	1	0	0
Plecoptera	Gripopterygidae	0	0	0	0
	Perlidae	6	9	2	4
Trichoptera	Brachycentridae	0	1	0	0
	Calamoceridae	2	1	0	1
	Glossosomatidae	0	4	1	0
	Helicopsychidae	5	5	2	2
	Hidropsychidae	5	10	3	6
	Hidroptilidae	2	2	0	1
	Hydrobiosidae	4	8	1	2
	Leptoceridae	5	10	1	2
	Limnephilidae	0	1	0	0
	Polycentropodidae	0	0	1	0
Diptera	Athericidae	3	3	0	0
	Blephariceridae	0	2	0	1
	Ceratopogonidae	2	5	0	0
	Chironomidae	6	13	5	6
	Dolichopodidae	0	0	0	1
	Empididae	1	2	1	0
	Limonidae	2	2	0	0
	Muscidae	0	1	0	0
	Psychodidae	0	1	0	1
	Simuliidae	4	3	1	2
	Tabanidae	0	1	0	0
	Tipulidae	2	5	0	3
Coleoptera	Dryopidae	1	0	0	1
	Elmidae adults	6	10	1	6
	Elmidae larvae	6	4	1	3
	Gyrinidae	0	0	0	1
	Psephinidae	1	1	0	0
	Ptilodactilidae	1	4	1	4
	Scirtidae	0	0	0	0
Odonata	Calopterygidae	2	0	0	0
	Coenagrionidae	1	0	0	0
	Gomphidae	2	3	0	1
	Libellulidae	0	3	0	2
Hemiptera	Corixidae	0	0	0	1
	Gerridae	1	0	0	0
	Naucoridae	2	4	0	5
	Veliidae	3	4	2	4
Megaloptera	Corydalidae	2	3	1	4
	Sialidae	1	0	0	0
Lepidoptera	Pyralidae	0	1	0	0
Actinedida	Hydrachnidae	2	4	2	1
Tricladida	Planaridae	2	3	1	1
Family richness (mean)		17.2	12.3	7.4	7.3
Family richness (range)		11–25	6–21	2–13	2–11
BMWP/Col index (mean)		72.8	59.8	37.9	36.1
BMWP/Col index (range)		48–117	32–86	9–73	9–63

Number in parentheses below the land use is the total number of sites within that category; the number in the table is how many of those sites contained a given family. Abbreviations as in Table 2. BMWP/Col, Biological Monitoring Work Party – Colombia.

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Significant differences in both family richness [$F(3, 31) = 8.79$, $p = 0.0002$] and BMWP/Col index [$F(3, 31) = 5.995$; $p = 0.0024$] were observed between land use groups. Both family richness and BMWP/Col index were significantly higher ($p < 0.05$) in (1) forested sites compared with urban and mining sites, and (2) agricultural sites compared with mining sites.

DISCUSSION AND CONCLUSIONS

Water systems

In general, the quality of water in community water supply systems and domestic taps was good, with low turbidity, nutrient and metal concentrations, neutral pH, and high dissolved oxygen. Nitrate and metal concentrations in all drinking water samples were well below EPA drinking water limits. Moreover, concentrations of metals and FIB were comparable with or lower than those measured in forested streams. These results indicate that drinking water is (1) generally not polluted relative to the natural water quality present in streams located in protected forests and (2) of higher quality than water from streams in agricultural, urbanized and mining areas.

The generally good water quality in community water systems is most likely due to the location of water sources away from areas with a significant degree of urban, agricultural or mining development. Most water systems tap into springs or small streams in forested areas uphill of the communities they serve, and 74 of the 87 water system samples were collected from community watershed reserves in which urban development, agriculture, cattle ranching and mining are prohibited and cattle are excluded with barbed wire fences. Log mean TC and EC concentrations were not significantly lower in samples from reserve water systems ($TC = 2.40 \pm 0.86$; $EC = 1.16 \pm 0.28$; $n = 74$) than in non-reserve water systems ($TC = 2.36 \pm 0.80$; $EC = 1.28 \pm 0.46$; $n = 13$) ($p > 0.05$). This is most likely because the small number of non-reserve water systems that we sampled, while not officially protected, typically had water sources located in forested, undeveloped areas.

Rivers and streams

With a few exceptions, the quality of water in Intag's rivers and streams was good. Turbidity, nutrient and metal concentrations were low, pH was neutral, and dissolved oxygen was high. Log mean TC levels were high (2.98–3.83) across all land use categories; however, because high concentrations of these bacteria were found even in protected forests with minimal human impact, it is likely that they have a natural rather than anthropogenic source. The USEPA (1986) set a single-sample standard of 235–575 CFU 100 mL^{-1} for EC in recreational waters, with the range related to the intensity of recreational use. Twenty-eight of 31 (90%) samples from agricultural areas, 17 of 17 (100%) samples from forested areas, 8 of 10 (80%) samples from mining areas, 10 of 13 (77%) samples from urban areas and 1 of 2 (50%) effluent samples from the Nangulví Ecotourism Complex had EC concentrations less than 235 (2.37 log) CFU 100 mL^{-1}. Only two (6%) agricultural samples, three (23%) urban samples and one (50%) Nangulví effluent sample had EC concentrations greater than 575 (2.76 log) CFU 100 mL^{-1}. These results indicate that Intag's rivers, especially those in forested areas, do not pose a risk to bathers in terms of waterborne illness. However, some rivers in agricultural and especially urbanized areas may contain faecal pollution and the pathogens associated with it.

Water quality parameters varied considerably within each land use category with the standard deviation often comparable in magnitude to the category mean (Tables 2–5). Nonetheless, some significant differences in constituents that may affect human health were observed. In addition to the elevated EC concentrations in urbanized and agricultural sites, significantly elevated As concentrations, sometimes exceeding the EPA drinking water limit for As, were observed at mining sites in Junín and urbanized sites in the Apuela and Guayllabamba Rivers. These elevated concentrations indicate that both mining exploration and urbanization may be associated with arsenic pollution to waterways in this region.

It is important to note that this study presents a snapshot of discharge and water quality in the Intag region, and the data presented here may not be representative of annual or longer-term average conditions. In particular, we observed very large fluctuations in discharge between sampling dates. Moreover, concentrations of nutrients, metals and other dissolved constituents can vary significantly depending on streamflow condition in tropical montane forests (Boy *et al.*, 2008). Measuring discharge and water quality parameters at multiple points in time under the full range of flow conditions would be necessary to characterize the fluxes of nutrients and metals passing through Intag's rivers.

Correlations between variables

The correlations observed between different water quality parameters within each land use category (Table 7) were difficult to interpret, possibly because of the large number of parameters measured and the small number of replicate sites within each land use category ($n = 7$, 9, 11 and 21 for urban, forest, mining and agriculture/pasture, respectively). Significant positive correlations between TC and EC in agricultural and water system sites suggest that the TC observed in these sites has a faecal source (either human or livestock). In mining sites, As was positively correlated with PO_4^- and inversely correlated with NO_3^-, whereas in urban sites, it was positively correlated with TC. These patterns could be indicative of distinct sources or mechanisms of As release; however, more research is necessary to clarify and explain these patterns.

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Table VII. Correlation matrix showing significant ($p < 0.01$) positive (+) or inverse (−) Spearman non-parametric correlations between water quality variables

	H^+	Log TC	Log EC	Phosphate	Ammonium	Nitrate	Mn	Cu	Zn	As	BMWP/Col	Family richness
Log TC												
Log EC		AG(+), WS(+)										
Phosphate												
Ammonium				FOR(+)								
Nitrate	MIN(−)		URB(+)	AG(−), WS(+)								
Mn	FOR(−)					AG(−), FOR(−)						
Cu	AG(+), MIN(+)				AG(−)	MIN(−)						
Zn	MIN(+)											
As		URB(+)		MIN(+)	WS(+)	FOR(−), MIN(−)	AG(+)					
BMWP/Col												
Family richness									AG(+)			

Land use category abbreviations (AG, FOR, MIN, URB and WS) indicate the land use category in which the correlation was observed. BMWP/Col, Biological Monitoring Work Party – Colombia; EC, *Escherichia coli*; TC, total coliform. We note that BMWP/Col and family richness were correlated, but these correlations are not included in the table because the indices are simply two ways of assessing the same attribute (aquatic invertebrate biodiversity).

Areas of concern

Although water quality in Intag was generally good, certain areas showed signs of potentially serious contamination. These included the Junín River and its tributaries in Junín's community forest (JUN4–8) and in the community of the same name (JUN1–2), the Guayllabamba River near El Chontal (RG1), the Apuela River immediately downstream of the town's wastewater discharge (AP2), a small stream receiving untreated sewage from the community of Pucará (PUC4 and AP3) and effluent from the Nangulví Ecotourism Complex (NAN1 and 2).

Samples collected from the Junín River and its tributaries (JUN1–2, 4–8) had much higher As concentrations than any other group of samples except for effluent from the Nangulví Ecotourism Complex (NAN1 and 2), which was likely affected by high As hydrothermal waters. The average (± standard deviation) As concentration in the Junín samples was $18.6 \pm 12.7\,\mu g\,L^{-1}$, compared with average concentrations of $0.8 \pm 1.0\,\mu g\,L^{-1}$ in all agricultural sites, $0.8 \pm 0.9\,\mu g\,L^{-1}$ in forested sites, $4.5 \pm 5.1\,\mu g\,L^{-1}$ in urban sites and $1.4 \pm 1.0\,\mu g\,L^{-1}$ in non-Junín mining sites. The Junín sites were the only ones in the study with high levels of As but no other indicators of serious contamination related to wastewater, such as high FIB and ammonium concentrations. They were also the only high As sites that local community members regularly use for drinking and bathing, which is a cause for concern because water at five sites (JUN4–8) had As concentrations exceeding the EPA drinking water standard of $10\,\mu g\,L^{-1}$.

As concentrations were highest at the mining borehole located within the community forest (JUN8; 36.5–$44.3\,\mu g\,L^{-1}$) and decreased in the downstream direction. Sites that did not receive water from the borehole because they were upstream of it or on different tributaries (JUN4, 5 and 7) also had high As concentrations (4.9–$29.1\,\mu g\,L^{-1}$). One explanation for this pattern is that other boreholes out of the 24 that were drilled and abandoned by Mitsubishi are adding high As water to Junín River system. This explanation is supported by water quality data collected by Bishimetals prior to drilling the boreholes, in which As concentrations in all river and stream samples except the Guayllabamba River were $5\,\mu g\,L^{-1}$ or less (Agencia para la Cooperación Internacional y Agencia para la Minería Metálica de Japón 1996). A second explanation is that the Junín River watershed is geochemically different from other nearby rivers, leading to much higher natural As concentrations and possibly also prompting interest in mining in the area. More detailed sampling is necessary to distinguish between these two explanations.

The small creek receiving untreated wastewater from Pucará (PUC4 and AP3), the Apuela River immediately downstream of Apuela's wastewater discharge (AP2), the Guayllabamba River near El Chontal (RG1) and two effluent

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samples from the Nangulví Ecotourism Complex (NAN1 and NAN2) all had high EC concentrations indicating faecal pollution. In addition, these sites showed other indicators of anthropogenic contamination. Concentrations of dissolved oxygen were low at NAN1 ($1.8\,\mathrm{mg\,L^{-1}}$), NAN2 ($5\,\mathrm{mg\,L^{-1}}$) and PUC4 ($4.3\,\mathrm{mg\,L^{-1}}$). RG1 was very turbid, with a Secchi depth of 5.75 cm. Phosphate concentrations were high in NAN1 ($610\,\mu\mathrm{g}\ PO_4^{3-}\text{-}P\,L^{-1}$), NAN2 ($543\,\mu\mathrm{g\,L^{-1}}$) and RG1 ($269\,\mu\mathrm{g\,L^{-1}}$). Ammonium concentrations were high at NAN1 ($2231\,\mu\mathrm{g}\ NH_4^{+}\text{-}N\,L^{-1}$), NAN2 ($243\,\mu\mathrm{g\,L^{-1}}$), RG1 ($299\,\mu\mathrm{g\,L^{-1}}$) and PUC4 ($64$–$332\,\mu\mathrm{g\,L^{-1}}$). As concentrations were very high in NAN1 and NAN2 (388 and $1316\,\mu\mathrm{g\,L^{-1}}$, respectively) and moderately elevated in RG1 ($12.9\,\mu\mathrm{g\,L^{-1}}$) and AP2 ($11.2$–$12.5\,\mu\mathrm{g\,L^{-1}}$). The very high As concentrations in the Nangulví effluent samples are most likely the result of hydrothermal inputs; hot springs elsewhere in north-central Ecuador have As concentrations of $2000 - 9.69 \times 10^5\,\mu\mathrm{g\,L^{-1}}$ (Cumbal *et al.*, 2010). The high As concentration in RG1 may originate from mining, industry and/or hydrothermal activity upstream. AP2 is not located near any mining, industry or hydrothermal inputs, and we hypothesize that high PO_4^{3-} and/or dissolved organic carbon in wastewater released at this site may liberate As naturally present in rocks and sediments into the water (Kalbitz and Wennrich, 1998; Smedley and Kinniburgh, 2002).

Conclusions and recommendations

The quality of Intag's drinking water systems, rivers and streams was generally good. On average, samples from drinking water systems had EC levels similar to those in forested streams, low nutrient and dissolved metal concentrations, low turbidity, and neutral pH. This indicates that the simple water systems present in the area, combined with DECOIN's community watershed conservation programme, are effective in providing most residents with water in a 'natural' or unpolluted state that is measurably better than that of rivers downstream of agriculture, urban development or mining activity. However, although TC and EC levels in water system samples were similar to those measured in forested streams and lower than those in streams impacted by other land uses, the presence of EC at any concentration in drinking water is considered unacceptable by both US (USEPA, 2009) and Ecuadorian (República del Ecuador, 2002) standards. Thus, we recommend that water be disinfected by boiling, filtration, exposure to ultraviolet radiation or chlorination (WHO, 2007) prior to drinking to reduce the risk of waterborne illness. Disinfection may not be necessary in Cuellaje, where the water is chlorinated, although we recommend further monitoring to ensure that the chlorination system consistently eliminates all EC. Disinfection is especially important for those with less natural resistance to waterborne pathogens: children, the elderly, people with compromised immune systems and tourists.

Many water quality indicators (concentrations of FIB, nutrients and dissolved metals) showed statistically significant differences among the land use categories considered in this study. Streams in protected forests tended to have the lowest concentrations of these constituents and the highest aquatic invertebrate diversity, with average values for other land use categories suggesting varying levels of impairment. The highest EC and ammonium concentrations and the lowest aquatic invertebrate diversity were found in urban sites, whereas the highest dissolved metal concentrations were found in mining sites. These results suggest that mining and urban development are the land uses that have the most severe effects on water quality in Intag. The effects of agriculture are less severe; however, because agriculture occupies much more of Intag's land area than urbanization or mining, it could affect a much greater proportion of the area's water resources. High EC and ammonium concentrations downstream of population centres are most likely the result of untreated wastewater discharges, because these pollutants often have a wastewater source and none of Intag's towns has a wastewater treatment system. Implementing low-cost wastewater treatment technology such as septic systems, constructed wetlands or lagoons (Massoud *et al.*, 2009) in the region's parish seats and other larger towns could reduce or eliminate the water quality impacts associated with these population centres. Further study is needed to determine which locations would benefit most from wastewater treatment and what type of technology is most appropriate.

Our results suggest three distinct sources of As in Intag's rivers: abandoned mining boreholes in Junín, hydrothermal inputs in Nangulví and inputs associated with wastewater in the Apuela and Guayllabamba Rivers. Hydrothermal inputs are natural and should not be considered pollution; however, it is important that people take care to avoid consuming these high As natural waters, because doing so may carry health risks. Further research is necessary to investigate the potential correlation between wastewater discharges and release of naturally present, but otherwise immobile, As from rocks. If such an association were found, it would be another important reason to treat the region's wastewater. Understanding which components of wastewater cause As release would also help determine the best wastewater treatment method, because removing these components would be a priority.

Finally, although our results are not sufficient to conclude that the abandoned boreholes in the Junín watershed are the source of the high As concentrations in that river system, we believe that they do suggest a relationship between boreholes and As contamination. Moreover, the observation that dissolved metal concentrations in Junín streams were

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elevated compared with those in other Intag streams but lower than those in areas of Ecuador (Tarras-Wahlberg *et al*., 2001; Appleton *et al*., 2004), Peru (Loayza-Muro *et al*. 2010) and Bolivia (Smolders *et al*. 2003) with a more developed mining industry suggests that if mining activity in Intag were to increase, metal concentrations could rise, possibly to harmful levels. Unless boreholes can be ruled out as a contributing factor to the high As concentrations in the Junín River, we recommend that any future borehole drilling projects in Intag be approached with extreme caution because of the risk that they could elevate As concentrations in surrounding rivers to dangerous levels for decades to come.

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APPENDIX

Site name	Site type	Tank or tap?	Community	Parish	River or stream	Land use	Latitude (N)	Longitude (W)	Sampling date	Altitude	Secchi depth	pH	Temp.	Dissolved oxygen	Dissolved oxygen	Discharge	Total coliform	*E. coli*	PO_4^{3-}-P	NH_4^+-N	NO_3^--N	SO_4^{2-}	Ni	Mn	Cu	Zn	Cd	Pb	As	Cr	BMWP/Col
							Decimal degrees	Decimal degrees	mm/dd/yy	m.a.s.l.	cm		°C	ppm	%	m^3/s	log CFU/100 mL	log CFU/100 mL	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	μg/L	index
AP4	River/Stream	–	–	Apuela	Toabunchi	AG	0.3586	78.4962	09/05/10	1662	100	5.5	–	–	–	3.90E−01 *	3.36	1.30	16	50	0.016	4.387	0.38	4.58	0.83	4.40	0.00	0.02	2.61	0.21	–
NV1	River/Stream	–	–	Apuela	Small tributary of Toabunchi	AG	0.3577	78.4968	10/05/10	1679	100	5	18	–	–	2.18E−04	2.15	1.00	43	21	0.193	5.004	0.42	1.17	3.25	5.78	0.08	0.05	1.30	0.28	–
NV2	River/Stream	–	–	Apuela	Small tributary of Toabunchi	AG	0.3578	78.4965	10/05/10	1650	100	5.5	18	–	–	1.27E−04	3.78	3.78	13	19	0.552	5.693	0.54	7.70	2.10	5.49	0.05	0.01	0.32	0.18	–
CUE1	River/Stream	–	–	Cuellaje	Cristopamba	AG	0.4104	78.5338	08/24/10	1799	100	5.5	–	–	–	8.76E−01	3.31	1.78	3	15	–	0.832	0.17	2.82	1.67	4.55	0.01	0.01	0.78	0.17	94
CUE1	River/Stream	–	–	Cuellaje	Cristopamba	AG	0.4104	78.5338	12/01/10	–	100	6.5	15.9	8.75	89	8.91E+00	2.15	1.00	8	8	0.042	0.691	0.19	2.93	1.85	6.59	0.00	0.01	0.76	0.19	70
CUE2	River/Stream	–	–	Cuellaje	Cristopamba	AG	0.4277	78.5287	08/24/10	1915	100	6	–	–	–	1.59E+00	3.03	1.60	8	17	–	0.854	0.18	2.39	1.50	4.43	0.01	0.01	0.77	0.17	63
CUE2	River/Stream	–	–	Cuellaje	Cristopamba	AG	0.4277	78.5287	12/01/10	–	100	6.5	15	8.8	87	7.23E+00 *	1.78	1.00	10	38	0.043	0.676	0.29	2.43	2.20	6.38	0.01	0.02	0.86	0.24	59
CUE7A	River/Stream	–	–	Cuellaje	Magdalena	AG	0.4257	78.5501	09/02/10	2065	100	5	–	–	–	1.67E−01	3.90	2.79	17	32	0.028	0.822	0.18	2.06	7.91	4.35	0.01	0.01	0.79	0.16	66
CUE7B	River/Stream	–	–	Cuellaje	Magdalena	AG	0.4258	78.5497	09/02/10	2069	100	5	–	–	–	1.65E−01	3.16	1.90	23	27	0.025	0.791	0.20	2.09	7.65	3.57	0.01	0.01	0.82	0.21	45
CUE7C	River/Stream	–	–	Cuellaje	Small tributary of Magdalena	AG	0.4226	78.5501	09/02/10	2053	100	5	–	–	–	6.65E−03	3.48	1.30	66	128	0.021	0.497	0.26	2.24	5.32	6.25	0.01	0.03	0.32	0.19	–
SJ1	River/Stream	–	–	Cuellaje	San Joaquín	AG	0.4064	78.5504	10/23/10	2077	100	7.8	14.3	8.7	85	4.60E−01	1.30	1.00	10	11	0.006	0.340	0.23	1.59	1.77	4.63	0.01	0.03	0.15	0.18	56
SJ1	River/Stream	–	–	Cuellaje	San Joaquín	AG	0.4064	78.5504	01/20/11	2077	100	6	13.9	7.99	78	2.57E+00	3.27	2.08	59	18	0.020	0.190	0.93	3.01	2.05	6.66	0.01	0.02	0.15	0.19	60
SJ2	River/Stream	–	–	Cuellaje	San Joaquín	AG	0.4117	78.5566	10/23/10	2138	100	7.84	15	8.48	85	3.30E−01	1.00	1.00	8	36	0.007	0.303	0.19	1.35	1.41	4.72	0.01	0.01	0.14	0.17	28
SJ2	River/Stream	–	–	Cuellaje	San Joaquín	AG	0.4117	78.5566	01/20/11	2138	100	6	13.6	8.11	78	2.71E+00	3.27	1.00	1	21	0.021	0.178	0.27	2.26	1.57	5.38	0.01	0.02	0.11	0.30	67
SJ3	River/Stream	–	–	Cuellaje	San Joaquín	AG	0.4130	78.5598	10/23/10	2193	100	7.81	14.2	8.7	85	1.10E+00	1.00	1.00	7	24	–	0.317	0.19	1.69	1.50	5.82	0.01	0.02	0.15	0.18	86
JUN3	River/Stream	–	–	Garcia Moreno	Chalguayacu	AG	0.2529	78.6743	09/07/10	1064	100	5	18	–	–	2.33E+00	2.97	1.00	20	45	0.008	1.579	0.18	3.08	9.89	7.07	0.02	0.01	2.64	0.17	–
JUN9	River/Stream	–	–	Garcia Moreno	Chalguayacu	AG	0.2824	78.6703	09/25/10	1320	100	5	14.2	–	–	9.36E−01	–	–	7	24	0.084	0.546	0.14	1.54	2.01	6.14	0.00	0.02	0.64	0.25	39
JUN9	River/Stream	–	–	Garcia Moreno	Chalguayacu	AG	0.2824	78.6703	11/16/10	1320	100	7.5	16.5	8.9	91	3.81E+00 *	3.90	1.60	11	33	0.018	0.567	0.22	1.22	3.07	6.25	0.00	0.02	0.71	0.27	80
MAG1	River/Stream	–	–	Garcia Moreno	Magdalena	AG	0.2445	78.7716	09/14/10	597.7	100	5	19	–	–	1.87E+00 *	3.44	2.26	0	15	0.043	2.105	0.16	0.51	0.78	4.18	0.00	0.01	0.21	0.18	–
MAG2	River/Stream	–	–	Garcia Moreno	Magdalena	AG	0.2744	78.7576	09/30/10	899.9	100	5	18	–	–	4.64E+00 *	3.85	2.30	8	13	0.053	2.055	0.16	0.67	0.82	4.43	0.00	0.01	0.21	0.18	105
MAG2	River/Stream	–	–	Garcia Moreno	Magdalena	AG	0.2744	78.7576	01/26/11	–	100	6.5	18.9	8.45	91	3.38E+01 *	3.90	2.08	1	20	0.128	0.931	0.32	0.85	1.07	16.26	0.06	0.05	0.10	0.35	17
MAG3	River/Stream	–	–	Garcia Moreno	Magdalena Chico	AG	0.2902	78.7581	09/30/10	1005	100	5	17.8	–	–	4.74E−01	3.72	2.00	5	31	0.116	3.748	0.16	0.29	2.34	4.39	0.01	0.01	0.09	0.14	47
MAG3	River/Stream	–	–	Garcia Moreno	Magdalena Chico	AG	0.2902	78.7581	01/26/11	–	100	6.5	18.5	8.25	88	3.51E+00 *	3.43	1.60	0	19	0.237	0.735	0.31	0.83	0.81	10.06	0.02	0.03	0.07	0.58	92
RV3	River/Stream	–	–	Garcia Moreno	Verde	AG	0.2471	78.8355	09/14/10	602.1	100	5	19	–	–	1.07E+00	3.11	2.00	7	26	0.174	0.788	0.14	0.25	0.57	3.70	0.00	0.01	0.29	0.18	–
RV3	River/Stream	–	–	Garcia Moreno	Verde	AG	0.2471	78.8355	12/14/10	679.2	100	6	20.3	9.35	104	–	1.80	1.00	0	21	0.206	0.452	0.15	0.39	0.95	5.01	0.00	0.01	0.24	0.23	59
RI1	River/Stream	–	–	Peñaherrera	Intag R. upstream of Nangulví discharges	AG	0.3274	78.5476	01/20/11	–	22.5	6.5	18	7.95	84	–	3.36	1.30	10	35	0.057	0.999	0.29	13.40	1.85	5.49	0.01	0.02	2.45	0.27	–
SR1	River/Stream	–	–	Plaza Gutierrez	Toabunchi	AG	0.3775	78.4724	08/20/10	1963	100	6	17.4	7.1	78	2.50E−01 *	3.81	1.00	74	21	–	4.270	0.41	12.90	0.58	3.95	0.00	0.01	3.45	0.21	28
SR1	River/Stream	–	–	Plaza Gutierrez	Toabunchi	AG	0.3775	78.4724	10/22/10	1963	40	8.4	14.1	8.7	87	1.01E+00	1.70	1.00	16	17	0.010	4.618	0.50	10.57	0.76	5.53	0.00	0.01	3.33	0.21	35
RQ1	River/Stream	–	–	Selva Alegre	Quinde	AG	0.279	78.5002	10/13/10	1882	100	6.5	14.7	8.62	85	1.28E−01	3.30	1.78	28	4	0.149	0.734	0.21	1.04	0.59	3.97	0.00	0.01	0.52	0.23	77
RQ2	River/Stream	–	–	Selva Alegre	Quinde	AG	0.2842	78.5148	10/13/10	1745	100	6.75	16.4	8.92	90	2.07E−01	3.90	2.53	26	6	0.064	0.700	0.26	3.85	0.59	4.48	0.00	0.01	0.62	0.22	67
RQ2	River/Stream	–	–	Selva Alegre	Quinde	AG	0.2842	78.5148	01/14/11	1745	61.5	6.5	15.2	8.06	81	3.94E+00 *	3.09	1.00	3	18	n.a.	0.317	0.44	21.06	1.05	4.56	0.00	0.06	0.52	0.59	0
CUE6	Spring	–	–	Cuellaje	Small spring	FOR	0.4250	78.5501	09/02/10	2084	100	5.25	–	–	–	–	3.45	1.60	23	40	0.009	0.519	0.20	1.46	2.71	7.26	0.01	0.01	0.29	0.18	–
LC1	River/Stream	–	–	Garcia Moreno	Los Cedros	FOR	–	–	09/15/10	–	100	5	–	–	–	2.46E−01	2.64	1.30	5	22	0.120	2.129	0.13	0.59	1.06	4.62	0.00	0.01	0.06	0.17	79
LC1	River/Stream	–	–	Garcia Moreno	Los Cedros	FOR	–	–	10/15/10	–	100	7.55	18.5	8.48	91	1.78E−01	–	–	7	4	0.130	2.283	0.15	0.69	1.08	4.57	0.00	0.01	0.06	0.17	54
LC1	River/Stream	–	–	Garcia Moreno	Los Cedros	FOR	–	–	01/27/11	–	48	6.5	17.4	8.2	86	6.73E+00 *	–	–	−2	16	0.170	0.354	0.31	0.93	1.74	9.39	0.01	0.03	0.08	0.32	16
LC2	River/Stream	–	–	Garcia Moreno	Magdalena Chico	FOR	0.3245	78.7770	09/16/10	1649	100	5	15.4	9.34	93	6.25E−02	2.53	–	5	29	0.140	0.383	0.15	0.18	0.47	4.70	0.00	0.01	0.11	0.63	103
LC2	River/Stream	–	–	Garcia Moreno	Magdalena Chico	FOR	0.3245	78.7770	10/16/10	1649	100	8.01	16.25	8.6	88	1.10E−01	–	–	5	8	0.138	0.421	0.15	0.23	0.45	4.59	0.00	0.01	0.10	0.61	64
LC2	River/Stream	–	–	Garcia Moreno	Magdalena Chico	FOR	0.3245	78.7770	01/27/11	1649	100	6.5	15.9	8.33	85	1.98E+00	–	–	0	20	0.146	0.102	0.22	0.36	0.59	9.58	0.00	0.02	0.10	0.74	52
LC3	River/Stream	–	–	Garcia Moreno	Small tributary of Los Cedros	FOR	–	–	10/16/10	–	100	7	18.6	7.9	85	2.38E−03	–	–	8	19	0.149	3.227	0.20	1.27	3.75	5.18	0.01	0.01	0.07	0.14	–
LF1	River/Stream	–	–	Plaza Gutierrez	Small tributary of Los Cedros	FOR	0.3610	78.4798	08/23/10	1895	100	6	–	–	–	1.97E−02	3.56	1.60	32	30	0.066	4.436	0.25	0.79	1.08	4.27	0.00	0.01	1.08	0.22	84
LF1	River/Stream	–	–	Plaza Gutierrez	Small tributary of Toabunchi	FOR	0.3610	78.4798	12/11/10	1895	100	6	15.8	8.4	84	–	3.90	1.00	37	58	0.174	2.173	0.73	1.51	3.69	9.56	0.01	0.07	0.92	0.36	150
LF2	River/Stream	–	–	Plaza Gutierrez	Toabunchi	FOR	0.3632	78.4850	08/23/10	1771	100	6	–	–	–	4.10E−01 *	3.26	1.00	16	32	0.006	4.124	0.35	6.24	0.62	4.96	0.00	0.02	3.17	0.21	87
LF2	River/Stream	–	–	Plaza Gutierrez	Toabunchi	FOR	0.3632	78.4850	12/11/10	1771	20	6	16.2	8.7	88	1.77E+00	1.00	1.00	16	39	0.046	3.688	0.88	19.19	2.72	6.17	0.01	0.08	2.28	0.27	79
SV1	River/Stream	–	–	Plaza Gutierrez	Toabunchi	FOR	0.3762	78.4252	08/25/10	2022	100	6	–	–	–	5.53E−01	3.26	1.00	16	20	0.056	1.820	0.53	43.76	0.57	4.97	0.00	0.01	1.44	0.23	55
SV1	River/Stream	–	–	Plaza Gutierrez	Toabunchi	FOR	0.3762	78.4252	01/17/11	2022	100	6.5	11.6	8.35	77	1.55E+00	3.61	1.00	14	26	0.007	3.821	0.61	19.27	0.42	5.05	0.00	0.01	1.52	0.18	40
SV2	River/Stream	–	–	Plaza Gutierrez	Small tributary of Toabunchi	FOR	0.3689	78.4238	08/25/10	2444	100	6	–	–	–	1.28E−02	3.79	1.00	13	25	0.120	0.510	0.18	0.32	0.34	3.96	0.00	0.02	0.59	0.20	53
SV2	River/Stream	–	–	Plaza Gutierrez	Small tributary of Toabunchi	FOR	0.3689	78.4238	01/17/11	–	100	6	12.8	7.9	75	7.88E−02	3.61	1.00	9	10	0.016	0.323	0.23	2.35	0.43	20.69	0.01	0.02	0.91	0.21	80

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SV3	River/Stream	–	–	Plaza Gutierrez	Small tributary of Toabunchi	FOR	–	–	01/17/11	–	100	6.5	12.8	7.95	75	2.10E−01		3.61	1.30	16	21	0.156	0.403	0.22	0.36	0.34	3.94	0.00	0.01	0.91	0.23	–
JUN1	River/Stream	–	–	Garcia Moreno	Junín	MIN	0.2758	78.6642	09/07/10	1245	100	5	18	–	–	4.04E−01		3.09	1.00	30	33	0.019	4.060	0.28	10.27	31.51	20.23	0.07	0.01	6.27	0.19	–
JUN1	River/Stream	–	–	Garcia Moreno	Junín	MIN	0.2758	78.6642	11/16/10		100	6	17.4	8.7	92	1.12E+00		2.86	1.00	24	54	0.222	2.997	0.36	10.18	44.40	25.95	0.07	0.02	5.52	0.31	31
JUN2	River/Stream	–	–	Garcia Moreno	Junín	MIN	0.2729	78.6652	09/07/10	1214	100	5	18	–	–	7.81E−01		2.89	1.00	25	27	0.017	4.032	0.30	9.83	30.44	19.05	0.07	0.02	6.38	0.20	–
JUN2	River/Stream	–	–	Garcia Moreno	Junín	MIN	0.2729	78.6652	11/16/10		100	6	17.6	8.6	91	1.20E+00		2.64	1.30	29	35	0.221	3.029	0.39	11.62	41.14	24.91	0.07	0.03	5.45	0.24	25
JUN4	River/Stream	–	–	Garcia Moreno	Junín	MIN	0.3103	78.6559	09/23/10	800	100	5	14.2	–	–	2.32E−02		1.00	1.00	84	52	0.026	4.437	0.26	8.96	73.30	12.75	0.10	0.01	27.45	0.15	36
JUN4	River/Stream	–	–	Garcia Moreno	Junín	MIN	0.3103	78.6559	11/17/10		100	6	15.7	8.55	87	1.12E−01	*	2.91	1.90	63	20	0.107	2.789	0.29	7.43	118.77	14.02	0.09	0.01	22.16	0.20	52
JUN5	River/Stream	–	–	Garcia Moreno	Small tributary of Junín	MIN	0.3117	78.6587	09/23/10	1660	100	5	15.5	–	–	1.69E−01		1.00	1.00	28	7	0.024	4.842	0.54	49.47	165.01	45.58	0.17	0.01	12.61	0.14	38
JUN5	River/Stream	–	–	Garcia Moreno	Small tributary of Junín	MIN	0.3117	78.6587	11/17/10		100	5.5	15.9	8.72	89	2.17E−01	*	2.75	1.00	11	23	0.087	4.293	0.74	73.13	221.62	79.26	0.23	0.01	4.92	0.16	25
JUN6	River/Stream	–	–	Garcia Moreno	Small tributary of Junín	MIN	–	–	09/23/10	n.m.	100	5	15.2	–	–	3.68E−03		3.39	2.08	99	12	0.010	23.150	0.28	101.84	3.33	10.56	0.05	0.01	21.69	0.15	63
JUN6	River/Stream	–	–	Garcia Moreno	Small tributary of Junín	MIN	–	–	11/17/10		100	6	16.3	8.4	86	6.20E−02	*	2.60	1.00	77	12	0.227	12.491	0.29	86.18	8.33	24.36	0.07	0.01	14.51	0.17	63
JUN7	River/Stream	–	–	Garcia Moreno	Small tributary of Junín	MIN	–	–	09/23/10	n.m.	100	5	14.5	–	–	2.39E−02		1.00	1.00	95	20	0.029	1.995	0.15	3.63	41.63	8.50	0.11	0.00	29.14	0.00	70
JUN7	River/Stream	–	–	Garcia Moreno	Small tributary of Junín	MIN	–	–	11/17/10		100	6	15.4	8.7	87	2.83E−01	*	1.00	1.00	51	36	0.100	1.064	0.29	2.79	175.91	15.76	0.07	0.01	23.10	0.19	43
JUN8	Borehole	–	–	Garcia Moreno	Borehole	MIN	–	–	09/23/10	n.m.	21.5	4.5	16.5	–	–	3.05E−03		2.68	1.00	321	21	0.007	25.945	0.30	442.25	3.53	5.16	0.04	0.01	44.28	0.19	–
JUN8	Borehole	–	–	Garcia Moreno	Borehole	MIN	–	–	11/17/10		100	6	18.4	0.25	3	–		3.90	1.00	320	36	0.003	25.358	0.19	426.26	2.54	1.51	0.05	0.00	36.42	0.00	–
RV1	River/Stream	–	–	Garcia Moreno	Verde	MIN	0.2408	78.8397	09/14/10	536.4	100	5	20	–	–	1.14E+00		2.48	1.30	5	38	0.249	0.808	0.33	0.44	0.88	5.87	0.00	0.01	0.38	0.22	–
RV1	River/Stream	–	–	Garcia Moreno	Verde	MIN	0.2408	78.8397	12/14/10	–	100	6.25	20.4	9.1	103	1.93E+01	*	3.00	1.74	7	23	0.272	0.471	0.28	0.72	1.61	12.21	0.00	0.02	0.25	0.27	35
RV2	River/Stream	–	–	Garcia Moreno	Small tributary of Verde	MIN	0.2467	78.8354	09/14/10	586.7	100	5	19	–	–	1.25E−01		1.00	1.00	7	47	0.588	0.888	0.24	0.38	2.09	15.61	0.00	0.02	0.76	0.29	–
RV2	River/Stream	–	–	Garcia Moreno	Small tributary of Verde	MIN	0.2467	78.8354	12/14/10	–	90	6.5	20.7	9.3	104	8.03E−01		2.64	1.00	32	48	0.505	0.467	0.53	3.26	3.13	5.42	0.00	0.01	0.44	0.34	9
QLL1	River/Stream	–	–	Selva Alegre	Small tributary of Quinde	MIN	0.2653	78.5591	10/13/10	1601	100	7.75	19.1	8.38	91	5.09E−03		3.90	2.51	35	25	0.300	2.677	0.50	5.57	0.72	3.53	0.01	0.01	2.70	0.28	73
QLL1	River/Stream	–	–	Selva Alegre	Small tributary of Quinde	MIN	0.2653	78.5591	01/14/11	–	3.5	7.5	19.1	7.47	81	1.25E−02		1.90	1.00	3	18	0.881	2.950	0.81	6.36	1.23	4.62	0.02	0.02	2.52	0.52	0
RQ3	River/Stream	–	–	Selva Alegre	Quinde	MIN	0.2642	78.5758	10/13/10	1292	100	6.75	19.9	8.41	92	8.15E−01		3.90	2.45	8	7	n.a.	0.965	0.27	10.37	0.88	2.89	0.01	0.01	2.57	0.23	39
RQ3	River/Stream	–	-	Selva Alegre	Quinde	MIN	0.2642	78.5758	01/14/11	1292	42.5	6.5	18.1	8.01	86	1.22E+01	*	2.79	1.00	21	45	0.259	0.730	0.29	15.15	0.78	3.91	0.01	0.01	1.37	0.34	20
NAN1	Wastewater effluent	–	–	Peñaherrera	Wastewater discharge from Nangulví Ecotourism Complex into Intag R.	TUR	0.3274	78.5476	01/20/11	–	100	7.75	23.5	1.8	21	–		3.90	3.48	610	2231	0.037	31.369	0.95	156.14	1.70	9.09	0.05	0.09	388.00	0.40	–
NAN2	Wastewater effluent	–	–	Peñaherrera	Wastewater discharge from Nangulví Ecotourism Complex into Intag R.	TUR	0.3274	78.5476	01/20/11	–	100	7.5	29	5	65	–		3.18	1.60	543	243	0.043	156.407	1.45	52.28	2.54	5.85	0.15	0.02	1316.05	0.32	–
AP1	River/Stream	–	–	Apuela	Toabunchi	URB	0.3541	78.5136	08/20/10	1533	100	6	15.3	8.17	83	1.80E+00	*	3.90	2.26	26	38	0.047	2.139	0.28	4.32	0.62	4.05	0.00	0.02	3.26	0.24	39
AP1	River/Stream	–	–	Apuela	Toabunchi	URB	0.3541	78.5136	10/25/10	1533	57	–	17.4	8.54	90	5.12E+00	*	3.06	1.00	22	8	0.055	2.376	0.36	4.44	0.86	4.21	0.00	0.01	3.57	0.25	70
AP2	River/Stream	–	–	Apuela	Apuela	URB	0.3537	78.5161	08/20/10	1517	100	6	18.4	7.67	83	1.97E+00	*	3.90	3.16	16	11	–	2.824	0.29	3.52	0.70	4.71	0.00	0.01	11.16	0.20	45
AP2	River/Stream	–	–	Apuela	Apuela	URB	0.3537	78.5161	10/25/10	1517	100	–	18.4	8.5	90	9.42E+00		3.20	1.60	25	31	0.154	3.375	0.37	4.40	0.92	4.85	0.00	0.01	12.49	0.22	39
AP3	River/Stream	–	–	Apuela	Small tributary of Toabunchi	URB	0.3585	78.4960	09/05/10	1703	100	5.5	–	–	–	–		3.90	2.08	20	31	0.079	1.323	0.52	0.84	3.69	20.92	−0.02	0.03	1.00	0.26	–
AP5	River/Stream	–	–	Apuela	Toabunchi	URB	0.3587	78.4961	09/05/10	1649	100	5.5	–	–	–	2.75E−01	*	3.21	1.00	19	53	0.014	4.367	0.39	4.65	0.90	4.81	0.00	0.02	2.85	0.23	–
PUC4	River/Stream	–	–	Apuela	Small tributary of Toabunchi	URB	–	–	08/26/10	–	61	5.5	–	–	–	7.67E−04		4.25	2.91	42	332	0.155	0.081	0.26	27.64	0.63	4.88	0.00	0.01	0.15	0.20	11
PUC4	River/Stream	–	–	Apuela	Small tributary of Toabunchi	URB	–	–	12/11/10	–	n.m.	6.5	23.7	4.3	50	3.96E−04		1.48	1.00	5	64	0.018	0.045	0.36	56.60	0.46	4.67	0.00	0.01	0.15	0.21	–
CUE8	River/Stream	–	–	Cuellaje	Cristopamba	URB	0.4000	78.5231	09/02/10	1788	100	5	–	–	–	1.41E+00		3.53	1.60	11	24	0.008	0.703	0.21	2.82	2.50	5.38	0.01	0.01	0.71	0.19	70
CUE8	River/Stream	–	–	Cuellaje	Cristopamba	URB	0.4000	78.5231	12/01/10	1925	100	6.5	16.3	8.7	89	1.16E+01	*	2.53	1.00	8	33	0.033	0.650	0.26	2.55	1.90	5.03	0.01	0.02	0.72	0.23	76
RG1	River/Stream	–	–	Garcia Moreno	Guayllabamba	URB	0.2345	78.7498	09/30/10	631.4	5.75	6	–	–	–	–		4.38	4.09	269	299	1.482	5.477	1.00	4.98	2.35	5.46	0.01	0.07	12.90	0.32	9
AP6	Water system	Tank	Parish Seat	Apuela	–	WS	0.3460	78.5107	11/22/10	1802	100	7.25	17.2	6.3	65	1.28E−03		2.20	1.30	–	–	0.044	2.398	0.36	5.84	2.15	5.81	0.02	0.02	2.48	0.24	–
AP7	Water system	Tank	Parish Seat	Apuela	–	WS	0.3460	78.5107	11/22/10	1802	100	6.5	16.6	6.8	70	1.65E−03		3.78	1.78	–	–	0.015	0.234	0.20	1.71	0.80	5.49	0.00	0.01	0.46	0.19	–
AP8	Water system	Tank	Parish Seat	Apuela	–	WS	0.3460	78.5107	11/22/10	–	–	–	–	–	–	–		1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
APC1	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–		1.00	1.00	-	–	–	–	–	–	–	–	–	–	–	–	–
APC2	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–		1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–

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APC3	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
APC4	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
APC5	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
APC6	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
APC7	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	3.64	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
APC8	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
APC9	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	-
APC10	Water system	Tap	Parish Seat	Apuela	–	WS	0.3562	78.5125	11/09/10	–	–	–	–	–	–	–	1.00	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PUC1	Water system	Tank	Pucara	Apuela	–	WS	0.3886	78.4524	08/26/10	2080	100	6	–	–	–	3.57E−03	2.41	1.00	5	66	0.195	1.035	0.38	0.69	0.78	6.26	0.01	0.04	0.21	0.26	–
PUC1	Water system	Tank	Pucara	Apuela	–	WS	0.3886	78.4524	11/27/10	2080	100	7	12.5	8.39	79	5.84E−03	1.00	1.00	13	9	0.087	0.127	0.18	0.13	0.41	5.44	0.00	0.01	0.18	0.28	–
PUC2	Water System	Tank	Pucara	Apuela	–	WS	0.3864	78.4553	08/26/10	2080	100	6	–	–	–	1.32E−04	3.48	1.30	28	16	0.067	0.104	0.13	0.11	0.29	4.33	0.00	0.01	0.18	0.26	–
PUC2	Water System	Tank	Pucara	Apuela	–	WS	0.3864	78.4553	11/27/10	2080	100	7.5	13.4	8.5	82	2.66E−03	1.00	1.00	32	5	0.369	0.886	0.24	0.08	0.26	2.58	0.00	0.01	0.19	0.25	–
PUC3	Water system	Tank	Pucara	Apuela	–	WS	0.3828	78.4750	08/26/10	2144	100	6	–	–	–	–	2.83	1.00	35	21	0.140	0.667	0.21	0.08	0.46	4.18	0.00	0.02	0.21	0.25	–
PUC3	Water system	Tank	Pucara	Apuela	–	WS	0.3828	78.4750	11/27/10	2167	100	8	14.2	9.5	96		1.00	1.00	–	–	0.348	0.755	0.43	0.12	0.49	18.66	0.00	0.02	0.22	0.28	–
PUCC1	Water system	Tap	Pucara	Apuela	–	WS	0.3653	78.4919	11/15/10	–	–	–	–	–	–	–	1.78	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PUCC2	Water system	Tap	Pucara	Apuela	–	WS	0.3653	78.4919	11/15/10	–	–	–	–	–	–	–	2.73	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PUCC3	Water system	Tap	Pucara	Apuela	–	WS	0.3653	78.4919	11/15/10	–	–	–	–	–	–	–	3.41	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PUCC4	Water system	Tap	Pucara	Apuela	–	WS	0.3653	78.4919	11/15/10	–	–	–	–	–	–	–	3.46	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–
PUCC5	Water system	Tap	Pucara	Apuela	–	WS	0.3653	78.4919	11/15/10	–	–	–	–	–	–	–	3.43	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PUCC6	Water system	Tap	Pucara	Apuela	–	WS	0.3653	78.4919	11/15/10	–	–	–	–	–	–	–	3.53	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PUCC7	Water system	Tap	Pucara	Apuela	–	WS	0.3653	78.4919	11/15/10	–	–	–	–	–	–	–	3.37	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PV1	Water system	Tank	Pueblo Viejo	Apuela	–	WS	0.3856	78.5068	11/23/10	1787	100	7	14.8	8	80	1.81E−03	3.78	1.00	38	35	0.052	0.437	0.26	3.42	1.01	3.49	0.02	0.02	0.53	0.20	–
PV2	Water system	Tank	Pueblo Viejo	Apuela	–	WS	0.3856	78.5068	11/23/10	1787	49.5	7	15.1	8.3	86	1.35E−04	3.76	1.60	13	98	0.133	0.547	0.26	0.25	0.65	4.45	0.02	0.02	0.47	0.20	–
PV3	Water system	Tank	Pueblo Viejo	Apuela	–	WS	0.3856	78.5068	11/23/10	1787	100	7	16.1	6.4	66	5.13E−05	3.02	1.00	45	23	–	0.916	0.35	0.62	0.52	22.11	0.17	0.03	0.78	0.24	–
PV4	Water system	Tank	Pueblo Viejo	Apuela	–	WS	0.3760	78.5107	11/23/10	2016	100	6.75	16.9	6.2	65	–	1.60	1.00	30	37	0.032	0.487	0.27	0.23	1.47	5.51	0.02	0.04	0.54	0.22	–
PVC1	Water system	Tap	Pueblo Viejo	Apuela	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.41	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PVC2	Water system	Tap	Pueblo Viejo	Apuela	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	1.78	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PVC3	Water system	Tap	Pueblo Viejo	Apuela	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	3.05	1.49	–	–	–	–	–	–	–	–	–	–	–	–	–
PVC4	Water system	Tap	Pueblo Viejo	Apuela	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	3.18	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–
CUE3	Water system	Tank	Parish Seat	Cuellaje	–	WS	–	–	08/24/10	–	100	6	–	–	–	–	3.40	1.60	41	23	0.365	0.139	0.22	2.90	0.55	3.18	0.02	0.01	0.59	0.23	–
CUE4	Water system	Tank	Parish Seat	Cuellaje	–	WS	–	–	08/24/10	–	100	6	–	–	–	–	2.85	1.60	63	52	0.055	0.168	0.22	5.32	4.24	4.94	0.04	0.05	0.45	0.21	–
CUE5	Water system	Tank	Parish Seat	Cuellaje	–	WS	–	–	08/24/10	–	100	6	–	–	–	–	1.00	1.00	57	41	0.163	0.143	0.22	0.40	1.28	5.05	0.03	0.01	0.51	0.21	–
CUEC1	Water system	Tap	Parish Seat	Cuellaje	–	WS	0.4020	78.5190	11/10/10	–	–	–	–	–	–	–	2.26	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
CHA1	Water system	Tank	Chalguayacu Alto	Garcia Moreno	–	WS	0.2806	78.6814	02/01/11	1474	65	6.5	18.3	9.55	102	–	2.83	1.90	28	21	0.589	0.111	0.20	1.05	0.62	9.06	0.00	0.02	0.24	0.24	–
CHA2	Water system	Tank	Chalguayacu Alto	Garcia Moreno	–	WS	0.2806	78.6814	02/01/11	1474	–	6.5	18.5	7.65	84	–	1.78	1.00	25	25	0.595	0.118	0.34	1.03	1.10	9.02	0.00	0.06	0.25	0.28	–
JUN10	Water system	Tank	Junin	Garcia Moreno	–	WS	0.2773	78.6651	02/01/11	1270	100	6.5	18	7.19	77	–	2.48	1.60	48	24	0.242	0.308	0.22	0.28	1.04	9.47	0.00	0.03	1.03	0.29	–
JUN11	Water system	Tank	Junin	Garcia Moreno	–	WS	0.2773	78.6651	02/01/11	1270	100	6.5	18	7.71	82	–	2.85	1.30	47	22	0.389	0.302	0.31	0.35	0.83	8.21	0.00	0.02	0.99	0.21	–
JUNC1	Water system	Tap	Junin	Garcia Moreno	–	WS	–	–	11/18/10	–	–	–	–	–	–	–	2.00	0.85	–	–	–	–	–	–	–	–	–	–	–	–	–
JUNC2	Water system	Tap	Junin	Garcia Moreno	–	WS	–	–	11/18/10	–	–	–	–	–	–	–	2.83	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
JUNC3	Water system	Tap	Junin	Garcia Moreno	–	WS	–	–	11/18/10	–	–	–	–	–	–	–	3.00	2.00	–	–	–	–	–	–	–	–	–	–	–	–	–
JUNC4	Water system	Tap	Junin	Garcia Moreno	–	WS	–	–	11/18/10	–	–	–	–	–	–	–	2.20	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
LI1	Water system	Tank	Limones	Garcia Moreno	–	WS	–	–	11/24/10	–	100	7	18.6	6.9	74	4.09E−05	3.15	1.00	108	43	0.694	0.136	0.30	18.77	0.64	5.22	0.00	0.02	1.51	0.26	–
LI2	Water system	Tank	Limones	Garcia Moreno	–	WS	–	–	11/24/10	–	100	7	19.2	6.7	74	1.31E−03	2.30	1.00	83	26	0.639	0.103	0.37	0.54	0.56	24.21	0.00	0.02	1.17	0.24	–
LI3	Water system	Tank	Limones	Garcia Moreno	–	WS	0.2415	78.6486	11/24/10	1403	100	6.5	19	8	80	–	3.27	2.15	76	24	0.660	0.209	0.22	0.31	0.57	2.28	0.00	0.01	0.26	0.24	–
LI4	Water system	Tank	Limones	Garcia Moreno	–	WS	–	–	11/24/10	1202	100	7	21.6	12.6	135	–	2.68	1.90	82	34	0.602	0.164	0.26	0.11	0.51	24.94	0.00	0.01	0.46	0.29	–
LI5	Water system	Tap	Limones	Garcia Moreno	–	WS	–	–	11/24/10	–	–	–	–	–	–	–	2.51	1.60	–	–	–	–	–	–	–	–	–	–	–	–	–
LI6	Water system	Tap	Limones	Garcia Moreno	–	WS	–	–	11/24/10	–	–	–	–	–	–	–	2.56	2.04	–	–	–	–	–	–	–	–	–	–	–	–	–
LI7	Water system	Tap	Limones	Garcia Moreno	–	WS			11/24/10	–	–	–	–	–	–	–	1.22	0.92	–	–	–	–	–	–	–	–	–	–	–	–	–
GM3	Water system	Tank	Parish Seat	Garcia Moreno	–	WS	–	–	10/06/10	–	100	5.5	16	–	–	–	2.95	1.00	30	41	0.026	0.034	0.38	2.89	0.73	5.19	0.00	0.01	0.33	0.18	–

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GM4	Water system	Tank	Parish Seat	Garcia Moreno	–	WS	–	–	10/06/10	–	100	6	16	–	–	–	3.72	1.94	44	13	0.183	1.794	0.64	6.79	0.59	3.47	0.01	0.01	0.26	0.22	–
GM1	Water system	Tap	Santa Rosa (GM)	Garcia Moreno	–	WS	0.2429	78.5962	10/06/10	1206	40.75	5	20	–	–	–	1.00	1.00	17	22	0.139	0.786	0.36	0.65	2.14	6.97	0.00	0.05	3.25	0.27	–
GM2	Water system	Tap	Santa Rosa (GM)	Garcia Moreno	–	WS	0.2441	78.5955	10/06/10	1254	100	6	40	–	–	–	2.90	1.00	32	44	0.006	0.377	0.56	0.76	1.66	23.30	0.02	0.04	0.43	0.30	–
CR1	Water System	Tap	El Cristal	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.66	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
CR2	Water system	Tap	El Cristal	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.86	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
CR3	Water system	Tap	El Cristal	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.73	2.15	–	–	–	–	–	–	–	–	–	–	–	–	–
CR4	Water system	Tap	El Cristal	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.78	1.60	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑ1	Water system	Tank	Parish Seat	Peñaherrera	–	WS	–	–	11/29/10	2005	100	6.5	16	7.6	79	1.65E−03	3.90	1.00	53	14	0.010	0.197	0.32	2.80	0.75	6.58	0.01	0.16	0.41	0.23	–
PEÑ2	Water system	Tank	Parish Seat	Peñaherrera	–	WS	–	–	11/29/10	2005	100	6.5	16.5	8	85	3.80E−03	2.79	1.00	24	24	0.005	0.117	0.27	0.62	0.58	3.72	0.02	0.02	0.24	0.24	–
PEÑ3	Water system	Tank	Parish Seat	Peñaherrera	–	WS	–	–	11/29/10	2005	–	–	16	8.5	80	–	2.93	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC1	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.62	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC2	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.53	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC3	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.20	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC4	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.41	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC5	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.45	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC6	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.48	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC7	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.66	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC8	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	2.56	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
PEÑC9	Water system	Tap	Parish Seat	Peñaherrera	–	WS	–	–	11/10/10	–	–	–	–	–	–	–	1.78	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
TI1	Water system	Tap	Tollo Intag	Peñaherrera	–	WS	–	–	12/16/10	–	100	7	–	–	–	–	1.90	1.00	22	31	0.007	9.781	4.49	2.11	1.93	4.51	0.01	0.01	1.29	0.22	–
TI2	Water system	Tap	Tollo Intag	Peñaherrera	–	WS	–	–	12/16/10	–	–	–	–	–	–	–	2.78	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
VF1	Water system	Tap	Villa Flora	Peñaherrera	–	WS	0.3348	78.5919	12/13/10	1733	100	6.5	18.7	8.1	87	–	1.90	1.00	19	10	0.011	0.126	0.26	0.50	2.92	55.75	0.00	0.32	0.16	0.19	–
VF2	Water system	Tank	Villa Flora	Peñaherrera	–	WS	0.3366	78.5951	12/13/10	1766	100	6.5	16.8	8.2	84	–	2.45	1.30	17	32	0.013	0.117	0.21	0.38	1.83	4.87	0.00	0.01	0.17	0.20	–
VF3	Water system	Tap	Villa Flora	Peñaherrera	–	WS	0.3351	78.5932	12/13/10	1748	–	–	–	–	–	–	2.15	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
VF4	Water system	Tap	Villa Flora	Peñaherrera	–	WS	–	–	12/13/10	–	–	–	–	–	–	–	2.34	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
VF5	Water system	Tap	Villa Flora	Peñaherrera	–	WS	0.3344	78.5913	12/13/10	1720	–	–	–	–	–	–	2.15	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–
VF6	Water system	Tap	Villa Flora	Peñaherrera	–	WS	0.3319	78.5882	12/13/10	1683	–	–	–	–	–	–	2.45	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
LD1	Water system	Tap	La Distinguida	Plaza Gutierrez	–	WS	0.3599	78.4835	01/14/11	–	–	5.5	–	–	–	–	2.60	1.00	28	23	0.139	0.332	0.32	0.21	2.13	4.43	0.00	0.05	0.57	0.49	–
LD2	Water system	Tap	La Distinguida	Plaza Gutierrez	–	WS	0.3599	78.4835	01/14/11	–	–	6.5	–	–	–	–	2.34	1.00	60	306	0.161	0.371	2.07	4.37	3.85	15.23	0.01	0.47	0.98	1.71	–
MEGH	Water system	Tap	La Distinguida	Plaza Gutierrez	–	WS	0.3599	78.4835	10/13/10	–	–	–	–	–	–	–	3.15	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–
SR2	Water system	Tank	Santa Rosa	Plaza Gutierrez	–	WS	0.3757	78.4620	08/25/10	2080	100	6	–	–	–	–	1.00	1.00	23	35	0.040	0.062	0.21	0.92	0.37	4.44	0.00	0.01	0.32	0.50	–
VG1	Water system	Tank	Parish Seat	Vacas Galindo	–	WS	0.3056	78.5656	02/09/11	1602	30	6	18.1	10.56	112	–	2.97	1.30	18	15	0.203	0.180	0.28	0.95	1.10	3.66	0.00	0.04	0.21	0.22	–
VG2	Water	Tap	Parish Seat	Vacas Galindo	–	WS	–	–	02/09/11	–	–	–	–	–	–	–	2.45	1.30	13	9	–	0.159	0.20	0.51	2.08	8.60	0.01	0.05	0.20	0.20	–

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