Assessing water appropriation and equity in the Coello and Bermellon watersheds: Application of Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM)

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A White Paper prepared for

Comité Ambiental en Defensa de la Vida, Cortolima, and UsoCoello, Colombia, and other users of MuSIASEM

(*Disclaimer.* Views presented in this White Paper are solely of the author)

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Abstract

The Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism Approach (MuSIASEM) can be used to assess the complex interactions between socio-economic and environmental facets of water resources in a region. It summarizes the ecological availability of water, as well as the socio-economic water use across sectors and industries. The goal of this study was to assess the applicability of the MuSIASEM framework for watershed planning in the Coello and Bermellon watersheds, Colombia, at local and regional scales. This paper provides information for local NGOs (Comité Ambiental en Defensa de la Vida (CADV) (Environmental Committee in Defense of Life)), the regional environmental authority (Cortolima), and the downstream irrigation district (UsoCoello). The study is useful for other case studies that may wish to adopt the MuSIASEM framework in a different region. CADV, UsoCoello and Cortolima are concerned about water availability in the Coello and Bermellon watersheds, especially as plans move forward to build the open-pit goldmine, La Colosa. Based on existing data from Cortolima and UsoCoello, the MuSIASEM frameworks and analysis for the Bermellon sub-watershed indicate that if downstream water use (i.e. UsoCoello) is not considered, 25% of the average annual flow is appropriated, and raises concerns about the potential over appropriation of water in the dry season. As scale increases to the Coello watershed, it reveals that there is potential for conflicting uses with the agricultural sector, as it is heavily dependent on water. Currently, water is being appropriated at quantities approaching the average annual water availability; i.e. Coello River is near stream closure (stream discharges that do not meet the demand of downstream uses during part or all of the year) (Molle, 2010; Roa-Garcia & Brown, 2004). Livelihoods in the region are dependent on water associated with agricultural activities, thus current concerns of water availability and appropriation should be evaluated and addressed before any decisions or policies regarding future industries are implemented. Future research needs include an analysis of data during dry seasons, a more precise water balance evaluation, incorporation of projected climate variability scenarios, an assessment of labour within campesino agriculture, as well as more accurate monitoring of La Colosa's water requirements during the four phases of mining activities (exploration, construction, operation and closure).

Contents

1. Introduction

In recent years the region of Tolima, Colombia has experienced growing concerns for the allocation and availability of water resources, specifically for the Coello watershed. The current water use as well as projected water use for future development in the watershed, have raised some concern for the availability of water from the Coello River. As environmental issues are invariably intertwined with politics, it has become increasingly important to study water availability and allocation in the region so that local communities may express their concerns, and so decisions at the government level be substantiated by empirical evidence.

Although there are alternative frameworks for assessing water resource allocation, this study assessed the applicability of the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism Approach (MuSIASEM) for groups involved in watershed planning (Lopez & Villarejo, 2014). The groups included the Comité Ambiental en Defensa de la Vida (CADV) (Environmental Committee in Defense of Life), a collective that integrates various NGO's, environmental groups, corporations, student collectives, farmers and indigenous peoples. CADV aims to promote public action to "defend water, life, territory, and the collective right to a clean environment" (Comité Ambiental en Defensa de la Vida, 2016). This white paper provides the Committee and the organizations under its umbrella with the information to assess the use of water by different sectors in the region (domestic, agricultural, and mining). Additionally, the results of this assessment provide information for Cortolima, the government entity that is responsible for managing environmental matters at the regional level. Their responsibilities include granting water concessions in the Coello Watershed, establishing fees for water use, granting environmental licenses to large projects, and creating plans for the region overall. Much of the raw data used for this project has been provided by Cortolima. Thirdly, this study is intended for UsoCoello, the irrigation district in the Coello Watershed.

The goal of this study was to apply the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism Approach (MuSIASEM) to assess existing water availability and use in the Bermellon and Coello watersheds, including the irrigation district, UsoCoello. MuSIASEM will also be used to project the impact that building an open-pit goldmine (La Colosa) would have on water use, allocation and livelihoods in the watersheds and in the downstream irrigation district. MuSIASEM was selected for this study as it is a unique framework that assesses both environmental and socio-economic facets of a natural resource (in this case, water). It considers the ability of an environmental resource to generate socio-economic output. The framework incorporates both environmental and socio-economic indicators.

Recommendations will be provided for the continuation of this study, and for the application of the MuSIASEM approach to other cases. This study will provide information to Cortolima and the organizations under CADV to facilitate planning for the different sectors in the Coello watershed and Bermellon sub-watershed.

1.1 Coello Watershed/Bermellon Sub-Watershed

The Coello watershed is 190,000 ha in area, and 125 km in length (Cortolima, 2005). It is in the department of Tolima - one of 32 departments that make up Colombia (Figure 1). Approximately 41,000 inhabitants use water from the Coello River (ibid).

The watershed is split into upstream, midstream and downstream areas (Nowak, 2013). The main source of water is surface water from the Coello River and its tributaries. The upper watershed (1,800 masl and above) is largely rural, with the city of Cajamarca as its main municipality. Cajamarca lies within the Bermellon sub-watershed (Figure 1). The middle watershed (1,000 – 1,800 masl) includes the capital city of Tolima, Ibague. The lower watershed (280 – 1,000 masl) includes the main Municipality El Espinal, as well as the irrigation district UsoCoello.

Precipitation data collected from 24 weather stations between the years 1987 – 2002 indicates that average annual precipitation within the entire basin is approximately 1,518 mm, with a range of 1,075 to 2,231 mm (Cortolima, 2005) (Raw Data Appendix E). The climate stations with the minimum and maximum average annual precipitations are both located in the upper watershed. The Coello watershed has a bimodal rainfall regime, meaning it experiences two wet seasons per year; the first is from March - May, and then in September - November. Two dry periods occur in January, February and March, and again in June, July and August. Average annual temperature within the watershed is 19.8 °C, with a range of 9.3 – 28.6 °C.

The Bermellon sub-watershed is approximately 10,464 ha in area and is located in the upper part of the Coello watershed (Figure 1). Annual average precipitation (recorded by 2 weather stations from the years 1987 – 2002) is 1,278 mm (Cortolima, 2005) (Raw Data Appendix D). There are two wet seasons as well as two dry seasons in the Bermellon sub-watershed, therefore there is seasonal variability.

The main crops grown in the Coello and Bermellon watersheds are coffee, rice, various fruit crops (e.g. mango), sorghum, cotton, and vegetables (mainly arracacha). The largest crop grown on an area basis is rice (Cortolima, 2005).

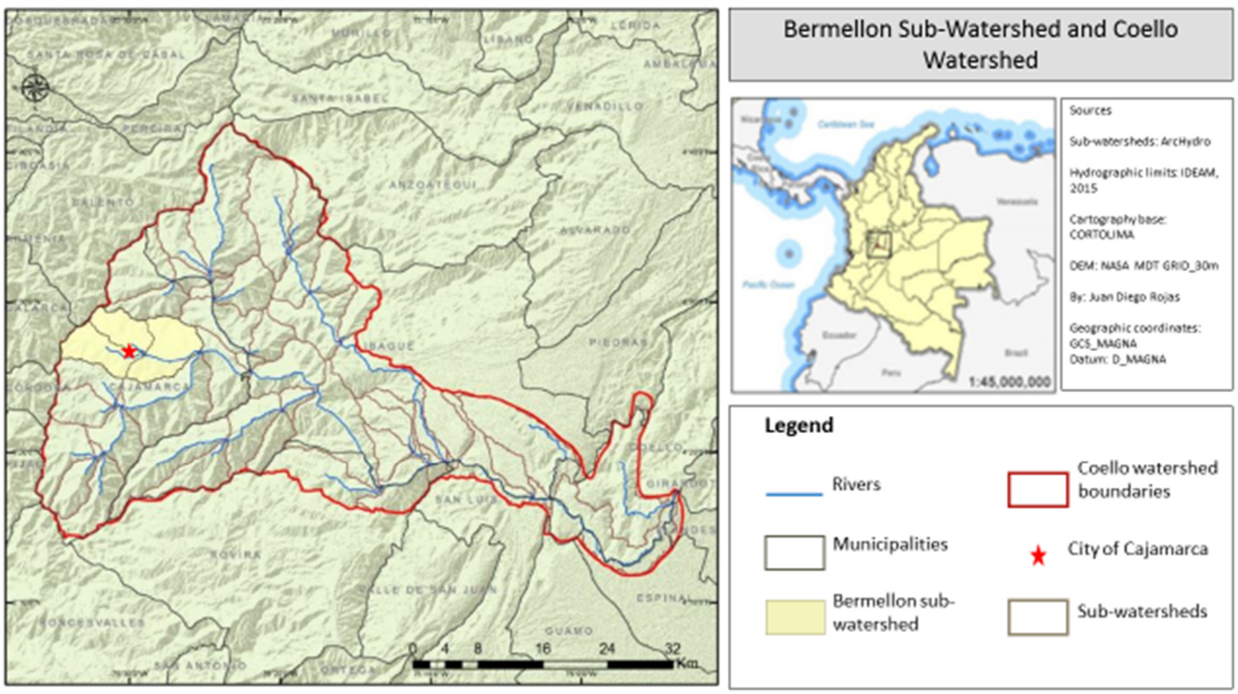

Figure 1: Coello watershed and Bermellon sub-watershed in Tolima, Colombia.

The water concessions in the region are granted by the regional environmental authority Cortolima. Cortolima grants concessions to the irrigation district, UsoCoello, from the Coello River (within the watershed) and the Cucana River (outside of the watershed). It has been reported that domestic, agricultural and industrial sectors withdraw more water than the concession grants them. A study conducted by Cortolima in 2005 concluded that real water use in the region (as opposed to concessions) reported a water scarcity index of 0.77 out of 1, indicating high water scarcity in the region (Cortolima, 2005).

1.2 UsoCoello

UsoCoello is 63,200 ha in area (UsoCoello, 2013). It is a downstream irrigation district owned by The Institute for Rural Development (INCODER) (Nowak, 2013). From 2004-2014, the average annual precipitation in the district was 1,461 mm (UsoCoello, 2016) (Refer to Appendix B for raw data, Appendix C for map of the weather stations in the district). UsoCoello is partially in the Coello watershed and receives an annual water concession from the Coello River of 9.64 m^3/s (ibid) (Appendix B). UsoCoello also has a concession from the Cucana River (10.91 m^3/s) which is outside the watershed boundary. The water from both rivers is ultimately used for irrigating 45,496 ha of crops annually (UsoCoello, 2016). The growing seasons for the crops are separated into Semester A (January – June) and Semester B (July – December), and annual crops that are grown year-round. Refer to Table 1 for a list of the main crops grown in each semester:

Table 1: Main crops grown per Semester for UsoCoello

Semester A (January – June)	**Semester B (July – December)**	**Annual Crops**
Rice	**Rice**	**Plantains**
Corn	**Cotton**	**Mango**
Cotton	**Sorghum**	**Pasture**
Beans	**Soy**	**Fish**
	Peanuts	

No crops are double-cropped throughout the year (UsoCoello, 2016). UsoCoello uses a portion of the water concessions (0.35 m^3/s) to supply three aqueducts: Espinal, Chicoral, and Coello. The irrigation district contends that any changes to the current distribution of water may affect the 43,000 rural and 96,000 urban inhabitants, and may affect the viability of the irrigation district (ibid). UsoCoello is considered essential for the food security of Colombia (Colombia Solidarity Campaign, 2011).

1.3 Open – pit gold mining and La Colosa

Anglo-gold Ashanti (AGA) is proposing to build a 1,400 ha open-pit gold mine called La Colosa in the Bermellon sub-watershed, close to the small urban center of Cajamarca (Anglogold Ashanti, 2015). La Colosa has concessions for surficial water intakes from the rivers La Quebrada, La Arenosa and La Colosa, which are tributaries of the Bermellon River (ibid). La Colosa has garnered support from some political parties in the region, however, environmental and agricultural groups have expressed concern for the repercussions on water sources and availability if the mine becomes operational (Colombia Solidarity Campaign, 2011). The capital city, Ibague is projected to hold a *consulta popular*, a democratic process where the citizens of the city vote to determine if the mine should be built in its current proposed location. A *consulta popular* was held in the city of Piedras in 2013, where it was voted that AGA would not be able to wash the gold from La Colosa in that region.

Figure 2 illustrates the connection between Bermellon, UsoCoello and La Colosa in the Coello watershed:

Figure 2: Diagram of interactions between Bermellon, UsoCoello and La Colosa in the Coello watershed (Anglogold Ashanti, 2015).

2. Methods

2.1 Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism Approach (MuSIASEM)

The framework for this project is the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism approach (MuSIASEM) developed by researchers at the University of Madrid. MuSIASEM is a diagnostic tool that is used for a given geographic entity, area or watershed; it aims to provide an assessment of the complex interactions between the socio-economic and environmental facets of a region (Lopez & Villarejo, 2014).

For this case study, MuSIASEM presents an annual water balance by assessing the distribution of water in the Bermellon and Coello watersheds across different sectors. It outlines various socio-economic uses of water, and the ability of water to generate economic return or contribute to livelihoods. Additionally, MuSIASEM provides a summary of the feasibility of proposed future scenarios within the geographic boundary. In this case study, it is used to assess the feasibility and viability of building the mine, La Colosa, in the Bermellon sub-watershed (which ultimately affects the entire Coello watershed). The framework does this in two ways:
First, by showing the amount of water that would be allocated to the project and comparing it to other water dependent activities; and second by assessing the social impact of the project in the form of how much water is used per hour of labour. Labour is a useful socio-economic indicator as it is representative of how people earn their livelihood in the region across commercial sectors. Therefore, if a significant quantity of water is associated with an hour of labour, it is indicative that livelihood in the region for that sector is dependent on water.

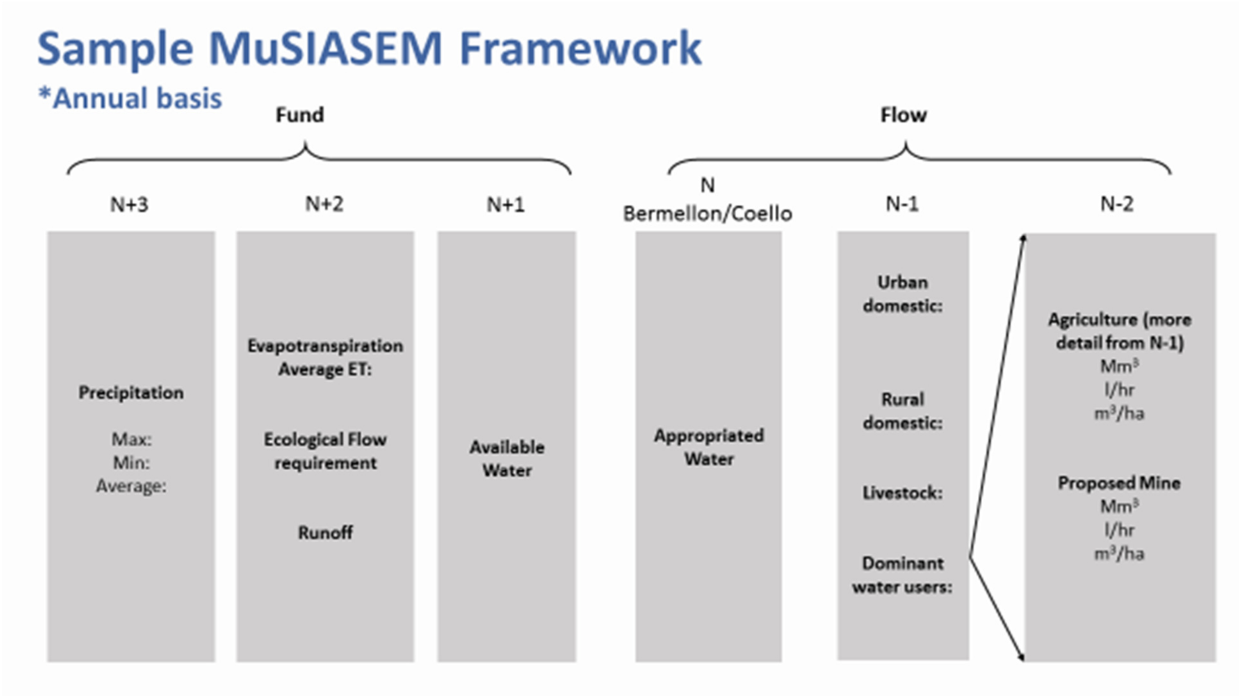

Figure 3: Sample MuSIASEM Framework

To formulate a MuSIASEM framework, acquired data is separated into the *fund* or *flow* category (refer to Figure 3). The funds (N+3, N+2, N+1) and the flows (N, N-1, N-2) are various scales within a watershed, from a large scale of how much water enters the watershed (funds), to various smaller scales of how this water is appropriated within the watershed (flows). N is defined as the watershed itself (Bermellon or Coello), and is a summary of the amount of water that is appropriated for different sectors: urban and rural domestic use, livestock, agriculture and industry (e.g., mining). This appropriated water is classified as a *flow*. The other *flows* are as follows: N-1 is a summary of water use; the water used in the urban domestic and rural domestic sectors, water used by cattle ranchers, and gross water use by major economic sectors (not including livestock). N-2 shows the net water use of the major sectors (in this case study, for both watershed scales, agriculture and mining are the two largest sectors). The water that is classified as a *fund* is how much surface water the environment provides that may be potentially appropriated for human use. N+1 is the amount of water available by the system after evapotranspiration, ecosystem requirements and runoff are accounted for (N+2), and N+3 is the amount of water that enters into the system as precipitation. Lastly, a series of flow/fund ratios are determined in order to characterize the rate of the flows across different scales. For example, a flow/fund ratio at the smaller agricultural scale would characterize the rate that water is used per hectare of crops. In this case study, all numbers are reported on an annual basis.

For this case study, MuSIASEM demonstrates the required water flows to maintain a socioecological system. The “metabolic” pattern of water is determined by the rate of withdrawals by society (the flow), and the capacity of the ecosystem to supply water for human activities (the funds). MuSIASEM for this case will focus on the allocation of water for current and potential users, ranging from small scale subsistence farmers to a large scale corporate mining operation.

Lastly, the MuSIASEM framework for this case study allows the user to assess if the stream is at stream closure. The water balance component of the framework can demonstrate whether or not stream discharges meet the demand of downstream uses during part or all of the year. If stream discharge does not meet the demand of downstream uses, the stream is at stream closure (Molle, 2010; Roa-Garcia, Brown, 2004).

2.2 Data sources

The majority of the data used for this project was obtained from Cortolima and UsoCoello. The raw data for the *funds* section (precipitation, evapotranspiration, runoff, ecological flow requirements) of the Bermellon framework were obtained from Cortolima. The raw data for level “N” and the *flow* section were obtained from Cortolima and Anglogold Ashanti. The raw data and detailed calculations are given in Appendix D. Only the calculated values are given here and displayed in the framework.

For the Coello framework, the raw data for the *funds* (precipitation, evapotranspiration, runoff, ecological flow requirements) were obtained from Cortolima. For level “N” and the *flow* sections, raw data was obtained from Cortolima, UsoCoello, as well as Anglo-gold Ashanti. The raw data and detailed calculations are given in Appendix E. Only the calculated values are given here and displayed in the framework.

3. Results, Discussion and Recommendations

3.1 Bermellon Sub-Watershed, and La Colosa

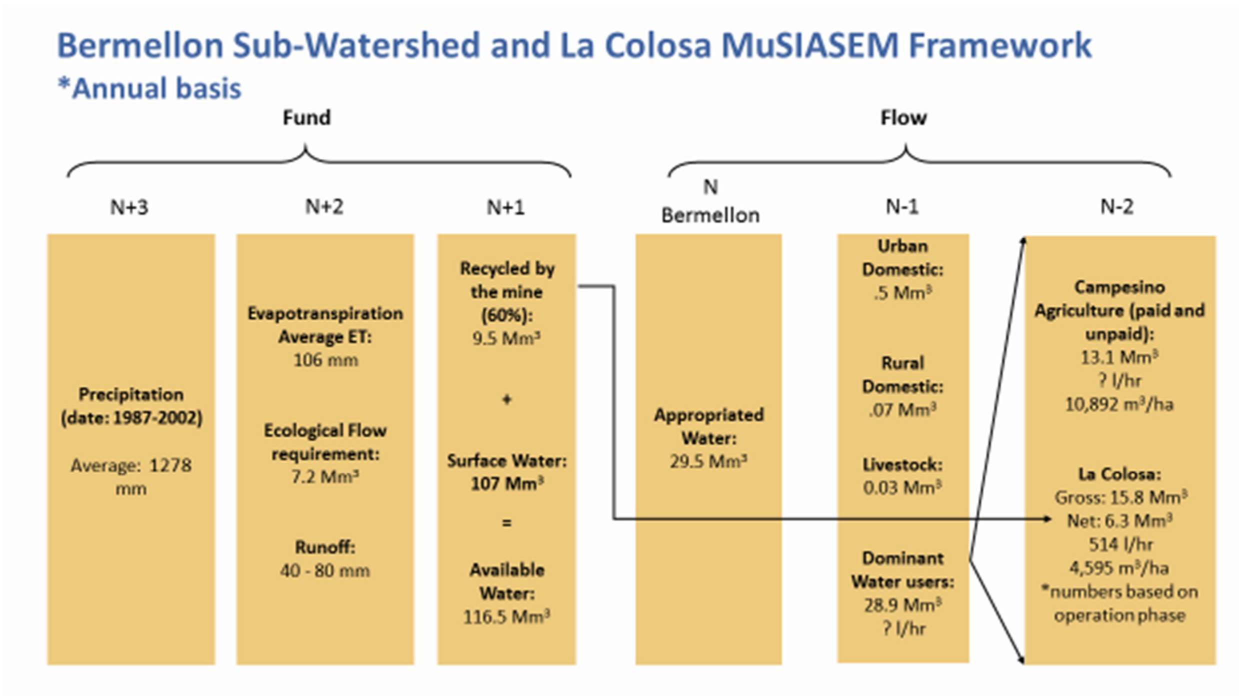

Figure 4: Bermellon Sub-Watershed Framework including the projected scenario with La Colosa gold mine

The amount of water available (N+1) is the sum of the available surface water (based on river flow rates from Cortolima, calculated by measuring precipitation and accounting for the amount of runoff, the ecological flow requirement and the evapotranspiration rates) as well as the amount of water the mine is projected to recycle (60%) (Anglo-gold Ashanti, 2015). As N indicates, 29.5 Mm^3 of water is appropriated in the Bermellon sub-watershed. Appropriated water is the sum of all the *flows*, or the various water uses in the region (N-1; rural domestic, urban domestic, livestock use, campesino agriculture and industrial use). Campesino agriculture (small scale diversified agricultural activity) and the projected mine are the dominant water users in the region (N-1, N-2). If La Colosa recycles 60% of its water, it would require 6.3 Mm^3 of new water per year, which is about half of the water used by campesino agriculture (which uses 13.1 Mm^3 of water). La Colosa's recycled water would be held in a tailings pond, then re-used. During its operation phase, La Colosa would be the largest water user in the region, and would be responsible for more than double the amount of water withdrawals within the watershed. If downstream water use (i.e. UsoCoello) is not considered, 25% of the average annual flow is appropriated. Given the seasonal variability in precipitation and streamflow, the Bermellon river may be at or near stream closure during the dry season.

Due to data gaps surrounding labour for campesino agriculture, livelihood dependency on water for agriculture compared to La Colosa is inconclusive, thus the livelihood component cannot be assessed at this scale. The recommendations section below addresses future research needs, so this information can be ascertained.

3.2 Uncertainties and Recommendations/Future Steps - Bermellon

Information from Cortolima on labour for campesino agriculture is unavailable for the Bermellon watershed. A study that measures the amount of labour expended on a campesino farm would require an assessment of the major crops grown in the region, as well as the proportion of labour that is hired labour (measured in jornales) and the proportion that is household labour (labour expended by family members or farm owners to cultivate agricultural products). One jornale is an 8 hour work day, and the number of jornales is the number of 8-hour work days required for a specific job (refer to Appendix F for more information about jornales). A study that measures the labour and types of labour in the Bermellon watershed would provide a more accurate description of livelihood dependency on water across sectors. A study to determine this information is currently being executed by students at the University of Tolima, and may be useful once completed.

To determine actual water usage (*flow*), an updated, detailed water balance should be conducted, as the data used for this study is more than 10 years old. A more detailed water balance would include updated land use information, as well as annual variability in streamflow and water use. The Bogota based group, Terrae, is currently working on a water balance for the Bermellon watershed that is projected to be completed in a few months. The amount of water from the Bermellon River and its tributaries that is used by UsoCoello should be incorporated into this water balance as it would give a more accurate representation of water use.

The Bermellon sub-watershed has a bimodal pattern of precipitation, with two marked periods of reduced precipitation (Jan-March, June-Aug). Once the water balance and labour studies are completed, it is key that stream flows and water use in the dry seasons be determined in order to assess if appropriated water exceeds available water.

Cortolima reports that minimum annual stream flow for Bermellon has previously been measured at 62.1 Mm3, which is a 53% reduction in the average annual available stream water used for the above MuSIASEM framework. For this dry year scenario, even without consideration of downstream water users, 48% of the average annual water available within Bermellon would be appropriated.

3.3 Coello Watershed, UsoCoello and La Colosa

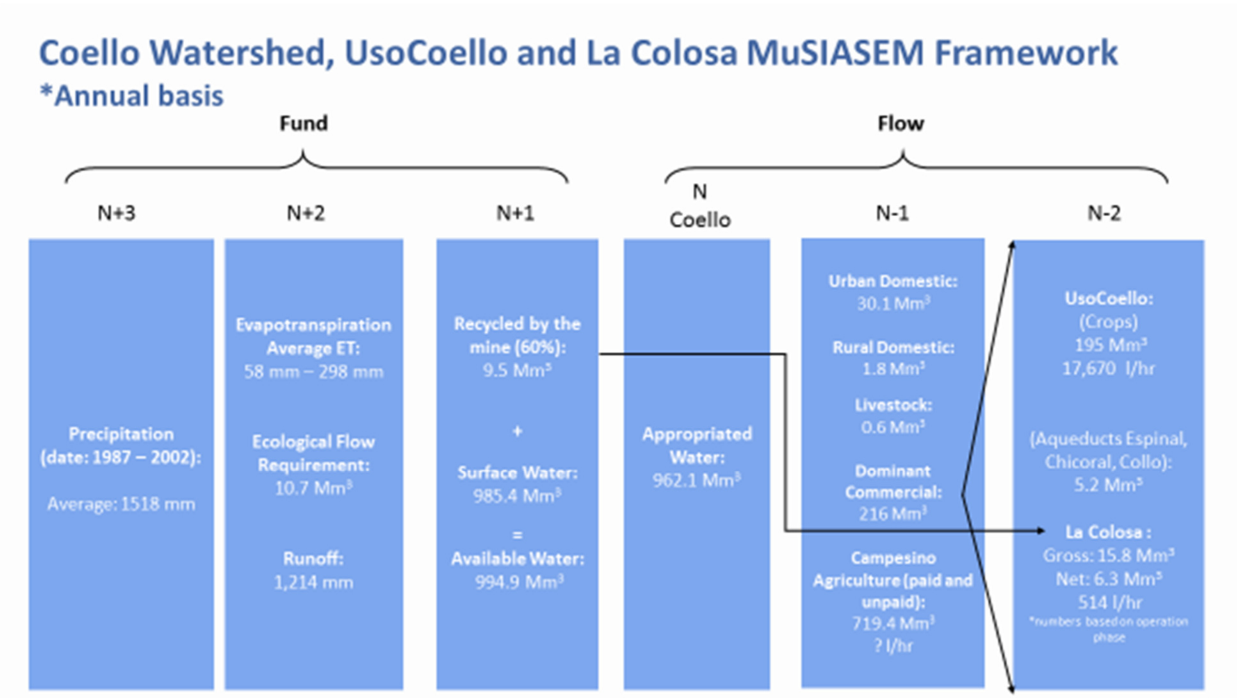

Figure 5: Current Coello watershed Framework with Projected Scenario of La Colosa

As scale increases from the Bermellon sub-watershed to the entire Coello watershed, it is evident that commercial agriculture and mining have a larger impact on the availability of water (Figure 5). Available water in the region is 994.9 Mm^3. Appropriated water is estimated at 962 Mm^3. There are uncertainties surrounding actual water use and availability, and actual numbers may vary, as users tend to draw more than they are given concession for. However, even accounting for a 10% difference in available water versus appropriated water indicates that the Coello River would be nearing stream closure with or without the projected scenario of the mine La Colosa.

At the Coello watershed scale, campesino agriculture uses 719.4 Mm^3 of water, and is therefore the largest water user in the region. At this scale, the commercial agricultural and mining sectors are the second largest users of water (216 Mm^3). A closer look at scale N-2 demonstrates that UsoCoello is responsible for the majority of commercial water usage (195 Mm^3 for crop usage, 5.2 Mm^3 contributed to domestic or mixed water providers) especially when compared to the mine (6.4 Mm^3 if 60% of water is recycled, 15.8 Mm^3 without recycling). Note, the actual recycling rate of La Colosa may vary if the mine becomes operational.

The current and proposed socio-economic activities in the Coello watershed are sustained on potential overuse of water funds. This is true even without the proposed mine, therefore it is prudent to suggest that no further development occur in the region until issues of water over-allocation are addressed.

Additionally, the MuSIASEM framework indicates that livelihoods in the region are largely dependent on commercial agricultural water use. UsoCoello primarily uses paid labourers (jornales) for its operations. UsoCoello uses 17,670 L of water per hour of paid labour, compared to 1,126 L/hr by the mine. Therefore, any re-allocation of water away from agriculture would have impacts on the livelihoods in the region.

3.4 Uncertainties and Recommendations/ Future Steps - Coello

It is recommended that future research in this area includes analysis of the funds and flows during the dry seasons or potential dry years. The average minimum stream flow for Coello measured by Cortolima was 14.4 m^3/sec (~452.9 Mm^3 annually), which is half of the average stream flow used for the current analysis. This has significant implications for water availability, especially if water use remains consistent. It is pertinent that a seasonal analysis be performed to assess potential water scarcity or water use in specific dry months of the year (Jan-March, June-Aug). Similarly, an analysis of climatic variability should be conducted in order to assess potential changes in stream flow in the future. The mine is projected to be in operation for 15-25 years, and climate variability will have to be considered for water availability into the future, to accommodate the duration of mine operations. This information could be ascertained via a more detailed water balance. A more detailed water balance would also include an updated study on land use and actual water use per land use in the region, especially for campesino agriculture, as the most water is used by this sector. An updated water balance is necessary, as the data from Cortolima used for this report is more than 10 years old.

The numbers used for the mine's water consumption were obtained from Anglo-gold Ashanti. A comparison to other data sources reveals that these numbers are conservative: IKV Pax Christi suggest that processing 20-35 million tons of ore per year at 1.0 m^3/sec per ton of ore would require 631 to 946 Mm^3 of water per year (2009). Even if La Colosa increased its recycling rate of water to 90%, this would still impact water use and availability. Other reports suggest the mine would use 31.5 Mm^3 of water per year (Colombia Solidarity Campaign, 2011). Although this number is significantly less than the numbers reported by IKV Pax Christi, it is still double that of what AGA has reported. Additionally, it is unclear whether the values used in this analysis included washing of the gold. It would be beneficial to compare water use for each phase of the mine, as this framework only assessed water use for the mine's operational phase (the remaining phases are the exploration, construction, and closing phases). To determine actual water usage, a comparison to other AGA gold mining projects should be made, and experts in the field of gold mining be consulted. Should Colombian NGO *Semillas de Agua* meet with AGA, I suggest they request data pertaining to actual water use and projected recycling rates. This information could help formulate a more accurate water balance and amount of water appropriated by the mine.

Similar to the recommendations for the Bermellon framework, the proportion of jornales relative to household labour in campesino agriculture is unknown. A study on campesino agriculture is recommended to determine the proportion of jornale versus household labour, as well as crops grown in the watershed that don't belong to UsoCoello. This would give a more accurate representation of livelihood dependency on water for campesino agriculture.

Though UsoCoello is not the biggest water user in the region, a study on agricultural water use efficiency could be conducted to assess how agricultural water consumption might be reduced. As this is a highly monitored area (Usocoello collects daily precipitation, stream flow and irrigation measurements), it may be easier to improve water use efficiency in commercial agriculture compared to campesino agriculture. For UsoCoello, improved water use efficiency for the more water-consumptive crops like rice may be necessary. Irrigation of rice requires 360.9 Mm^3 of water per year, whereas all other crops grown in UsoCoello combined require 52.9 Mm^3 (UsoCoello, 2016). Based on the data provided by UsoCoello, irrigating rice requires 14,361 m^3/ha, whereas the other crops combined average 3,151 m^3/ha (Appendix

B). Additionally, an effort should be made by Cortolima to determine the actual water use by UsoCoello; it is possible that withdrawals exceed their water concessions.

Lastly, it is important to note that rural domestic and urban domestic may include mixed use water, and the percentage that is allocated to each use is unclear. For example, a patio gardens may be included in the rural domestic water use. Therefore, it would be beneficial to obtain a clearer understanding of what average domestic water use entails.

4. Conclusion

MuSIASEM provides a useful toolkit to summarize the existing water distribution and balance in a watershed, while providing an opportunity to assess how future water-dependent projects may affect this distribution and balance. Additionally, it is unique in that selected indicators may assess the connection between socio-economic activities and a natural resource. The framework can be applied to other case studies, however this is dependent on the quality of data available in the region. The quality of the data supplied by Cortolima and UsoCoello was high enough overall that the framework was able to effectively communicate the current and projected distribution of water in the region.

As observed in this case study, MuSIASEM allows for a summary of water-dependent socio-economic activities, thus allowing an evaluation of the dependency of livelihoods and commercial activities on water. In this case study, the Bermellon sub watershed is currently appropriating 25% of the average annual flow, if downstream water use (i.e. UsoCoello) is not considered. The Bermellon river may be at or near stream closure during the dry season, if seasonal variability in precipitation and streamflow are considered.

Due to the fact that labour requirements for campesino agriculture were not available, a comparison of livelihoods between campesino agriculture and La Colosa was not made. As scale increased to the Coello watershed, it became clear that current agriculture (campesino and commercial agriculture), even without the projected mine scenario, uses enough water that the Coello River at or near stream closure. Although the proposed industry appears to not have as great an impact on water allocation compared to the current water use by the agricultural sectors in the region, it is prudent to suggest that no further development occur until current water-use is re-evaluated in a detailed water balance, and potential issues with over-abstraction addressed. Additionally, the MuSIASEM framework for the Coello watershed demonstrates that livelihoods in the region are dependent on agriculture and water, therefore (re-)allocating water to another sector would impact livelihoods.

The frameworks constructed for this study used annual average data. This is a limitation, as stream flow (and potentially water appropriation) vary throughout the year. The frameworks for this case study do not directly consider the dry seasons of the study area, which span three months in length each. Stream flow and appropriated water may vary during the dry season. Future frameworks should address this, and different time-scales used.

This case study is a first step in addressing the complex issues and interactions surrounding this watershed. Specific data gaps must be filled for this study to move forward. This involves analysis during dry seasons and projected climatic variability scenarios, a more detailed water balance, a labour study for campesino agriculture, as well as a more accurate determination of the La Colosa water requirements.

5. Acknowledgements

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7. Appendices

Appendix A: List of key contacts by organization

UsoCoello: Engineer Luis Eduardo Murillo Cardoso

Cortolima: Fernando Mauricio

Semillas de Agua: Jorge Rubiano

University of Tolima: Renzo Alexander Garcia Parra

Terrae: Andres Castillo

Appendix B: UsoCoello Raw Data 2016

La asociación tiene concesión de aguas a nombre de la misma.

- La TUA (Tarifa del uso del agua) se paga desde el año 1996 (del río Coello) Res 473 del 12 de Mayo de 2006
- El volumen de agua concesionada es la siguiente: Río Coello 9.64m^3/s Res: 473 del 12 de Mayo del 2006
- **CULTIVOS, Has CULTIVADAS, PRODUCCIÓN Y JORNALES**

ZONA DE INFLUENCIA DEL DISTRITO DE RIEGO DE Usocoello				
ÁREA PRODUCCIÓN Y JORNALES POR HECTÁREA				
CULTIVO	ÁREA SEMBRADA Ha	PRODUCCIÓN Kg/Ha	PRODUCCIÓN TOTAL Tn/año	JORNALES
ARROZ	25202,78	6875	173269,1125	504055,6
MAIZ	11686,71	5000	58433,55	409034,9
ALGODÓN	4464,98	2700	12055,446	111624,5
FRIJOL	383,81	800	307,048	6908,58
SORGO	57,08	3500	199,78	742,04
SOYA	180,90	3000	542,7	904,5
MANI	29,53	1500	44,295	324,83
PLATANO	14,64	15970	233,8008	907,68
PASTOS	427,03	5500	2348,665	8967,63
MANGO	3000,00	22000	66000	336000
POZOS (PECES)	48,67	18750	912,5625	924,73
TOTAL	45496,13		314346,9598	1380394,9

- **DEMANDA DE AGUA POR CULTIVO Y RIEGO**

CONSUMO REAL DE AGUA POR COSECHA		
	SEMESTRE A	SEMESTRE B
CULTIVO	CONSUMO (m^3)	CONSUMO (m^3)
ARROZ	191.747.455,00	170.199.974,00
SECANO (MAIZ, ALGODÓN, FRIJOL, FRUTALES, POZOS Y OTROS)	34.209.355,00	18.751.191,00
TOTAL	225.956.810,00	188.951.165,00

El **módulo de riego** de los principales cultivos es el siguiente:

  - Arroz: 2 L/s/Ha
  - Maíz: 2 L/s/Ha
  - Algodón: 2 Ls//Ha

- **AGUA APORTADA POR USOCOELLO A LOS ACUEDUCTOS** Es de 0.35m^3/s a los acueductos de Espinal, Chicoral y Coello

La población rural afectada sería de:

- Espinal: 20.439 habitantes
- Guamo: 18.428 habitantes
- Flandes: 4.234 habitantes

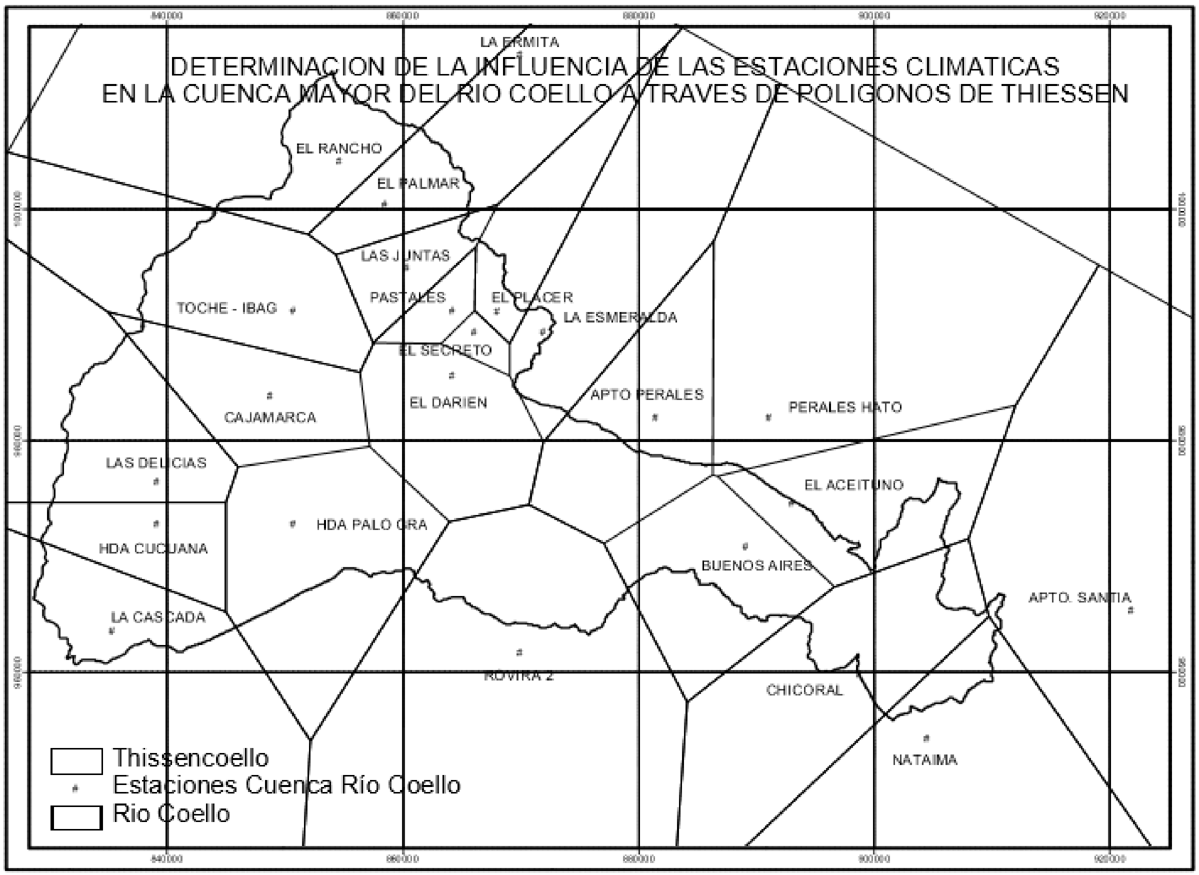
La población urbana afectada sería de:

- Espinal: 55.787 habitantes
- Guamo: 16.353 habitantes

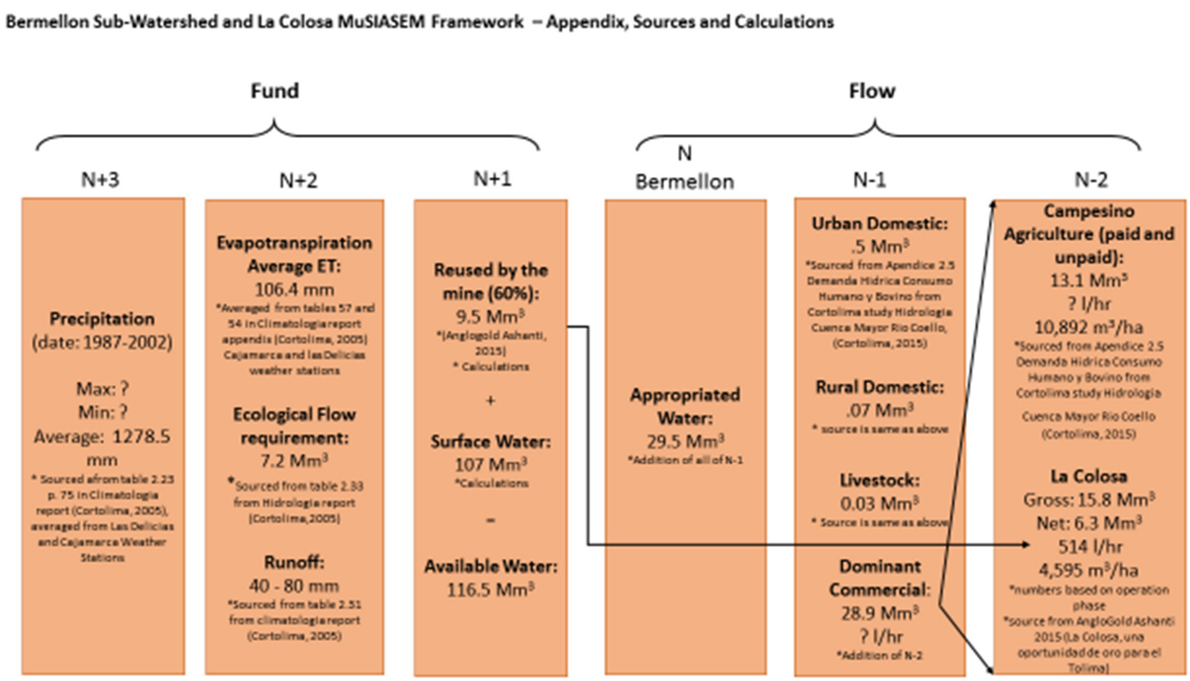
Flandes: 23.994 habitantes

Appendix C: Climate Stations for Coello watershed

p. 72 Climatologia (Cortolima, 2005).



Appendix D: Bermellon Framework Raw Data, Sources and Calculations



N+3 raw data and calculations:

Tabla 2.23. Precipitación Media Mensual

PRECIPITACION TOTAL (mm) - CUENCA COELLO 1987-2002							
ESTAC. Nº	ESTACION	X	Y	PreMe.Tot	Area(Hct.)	Desvio (mm)	Desvio (%)
1	LA CASCADA	836888,4	963400,3	1323,3	7291,26	-194,5	-12,81
2	EL RANCHO	855468,2	1003924,2	1491,8	8518,47	-26,0	-1,71
3	EL PALMAR	859161,3	1000230,5	1317,4	7270,22	-200,4	-13,20
4	LAS JUNTAS	861001,6	994696,8	1450,1	6049,95	-67,7	-4,46
5	EL PLACER	868395,6	990997,4	1953,8	2163,10	436,1	28,73
6	HDA CUCUANA	840607,5	972611,3	1074,5	9200,29	-443,3	-29,20
7	LAS DELICIAS	840614,5	976298,5	1284,6	13099,61	-233,2	-15,36
8	TOCHE - IBAGUE	851744,5	991026,3	1113,2	15759,47	-404,6	-26,65
9	LA ESMERALDA	872092,8	989148,1	1557,9	2285,14	40,2	2,65
10	CAJAMARCA	849880,7	983655,5	1272,3	14159,70	-245,5	-16,17
11	EL DARIEN	864686,2	985473,2	2185,7	16805,59	668,0	44,01
12	HDA PALO GRANDE	851711,3	972590,9	1639,8	15621,50	122,1	8,04
13	PASTALES	864695,4	991003,5	2231,1	3068,32	713,4	47,00
14	EL SECRETO	866542,5	989157,0	1852,2	1535,12	334,5	22,04
15	ROVIRA 2	870199,6	961499,8	1733,6	13359,42	215,9	14,22
16	APTO PERALES	881332,4	981760,6	1635,6	8908,85	117,9	7,76
17	PERALES HATO OPIA	890583,3	981747,7	1349,8	103,49	-168,0	-11,07
18	BUENOS AIRES	888718,3	970690,3	1457,9	11914,10	-59,8	-3,94
19	EL ACEITUNO	892423,9	974372,1	1357,5	6180,85	-160,3	-10,56
20	CHICORAL	897957,0	959619,0	1416,1	11125,76	-101,7	-6,70
21	NATAIMA	903502,6	954082,9	1518,3	3477,91	0,5	0,04
22	APTO. SANTIAGO VILA	920168,9	965125,1	1174,0	268,06	-343,8	-22,65
Valor Precipitación Promedio				1517,8	178166,21		
Valor Precipitación Promedio Ponderada				1503,0			

Las Delicias: 1284.6 mm

Cajamarca: 1272.3mm

Average: 1,278.45 mm

N+2 raw data and calculations:

Evapotranspiration:

Tabla 54

CALCULO DE EVAPOTRANSPIRACION POTENCIAL POR THORNTHWAITE
CUENCA RIO COELLO - PERIODO 1987 - 2002

ESTACION : LAS DELICIAS — ELEVACIÓN : 2070 m.s.n.m. — CODIGO : 2121013
LATITUD : 4° 23' — DEPARTAMENTO : TOLIMA
LONGITUD : 75° 31' — MUNICIPIO : CAJAMARC

MES	T°C	i	Etp. T	F	ETP	P mm
ENERO	16,2	5,93	8,32	1,00	8,32	52,7
FEBRERO	16,6	6,15	8,66	0,93	8,05	56,9
MARZO	16,5	6,10	8,57	1,03	8,83	89,5
ABRIL	16,1	5,87	8,23	1,02	8,40	150,4
MAYO	16,3	5,98	8,40	1,06	8,91	195,2
JUNIO	16,3	5,98	8,40	1,03	8,65	128,2
JULIO	16,8	6,26	8,83	1,06	9,36	96,5
AGOSTO	16,3	5,98	8,40	1,05	8,82	79,3
SEPTIEMBRE	15,6	5,60	7,82	1,01	7,90	138,9
OCTUBRE	15,6	5,60	7,82	1,03	8,05	117,2
NOVIEMBRE	15,9	5,76	8,07	0,99	7,99	100,7
DICIEMBRE	16,0	5,82	8,15	1,02	8,31	79,1
Σ		**71,05**				

i = Índice Térmico Mensual
Etp. T = Evapotranpiración Potencial Teórica
F = Factor de Corrección de Thornthwaite
ETP = Evapotranspiración Potencial Corregido
a = Función dependiente del Índice Térmico Mensual (i) = **1,64**

Tabla 57

CALCULO DE EVAPOTRANSPIRACION POTENCIAL POR THORNTHWAITE
CUENCA RIO COELLO - PERIODO 1987 - 2002

ESTACION : CAJAMARCA — ELEVACIÓN : 1920 m.s.n.m. — CODIGO : 2121510
LATITUD : 4° 27' — DEPARTAMENTO : TOLIMA
LONGITUD : 75° 26' — MUNICIPIO : CAJAMARC

MES	T°C	i	Etp. T	F	ETP	P mm
ENERO	17,3	6,55	9,15	1,00	9,15	126,4
FEBRERO	17,7	6,78	9,52	0,93	8,86	119,9
MARZO	17,5	6,66	9,34	1,03	9,62	149,7
ABRIL	17,1	6,43	8,97	1,02	9,15	183,8
MAYO	17,3	6,55	9,15	1,06	9,70	175,6
JUNIO	17,3	6,55	9,15	1,03	9,43	93,2
JULIO	17,9	6,90	9,71	1,06	10,30	81,5
AGOSTO	17,4	6,61	9,24	1,05	9,71	97,0
SEPTIEMBRE	16,7	6,21	8,60	1,01	8,69	184,4
OCTUBRE	16,6	6,15	8,51	1,03	8,77	148,6
NOVIEMBRE	16,9	6,32	8,78	0,99	8,70	140,9
DICIEMBRE	17,0	6,38	8,87	1,02	9,05	92,9
Σ		**78,08**				

i = Índice Térmico Mensual
Etp. T = Evapotranpiración Potencial Teórica
F = Factor de Corrección de Thornthwaite
ETP = Evapotranspiración Potencial Corregido
a = Función dependiente del Índice Térmico Mensual (i) = **1,75**

The Bermellon watershed is monitored by Las Delicias and Cajamarca weather stations. Added up the ETP columns and averaged them:
Las Delicias: 101.59
Cajamarca: 111.13
Average: 106.36

Ecological Flow Requirement

Table 2.33 from Hidrologia report (Cortolima, 2005)

RIO BERMELLON		Q. Perales	52,61	21,43	**0,11676**	0,04756	0,01189	0,10487
	Q. Guala		50,79	27,83	**0,67911**	0,37211	0,09303	0,58608
	Q. Chorros Blancos	Q. El Rincón	53,12	29,25	**0,08568**	0,04718	0,01180	0,07389
		Q. Chorros Blancos 2	53,12	29,25	**0,39813**	0,21922	0,05481	0,34332

CUENCA	SUBCUENCA	MICROCUENCA	Precip. Max. Diaria		CAUDAL MEDIO (m3/seg)	CAUDAL DE REPARTO (m3/seg)	Q. ECOLOGICO (m3/seg)	Oferta Hídrica Neta (m3/seg)
			Vr. Med	Vr. Mín.				
	TOTAL Q. CHORROS BLANCOS				**0,48381**		**0,05481**	**0,42900**
		Q. Espejo	55,79	31,13	**0,05828**	0,03252	0,00813	0,05015
	Río Bermellon 1		55,79	31,13	**0,60685**	0,33861	0,08465	0,52220
	Río Bermellon 2		54,72	34,43	**1,45174**	0,91344	0,22836	1,22338

Q Ecological: Includes Q.Guala, Q. Chorros Blancos, Q. Espejo, Rio Bermellon 1, Rio Bermellon 2 = 0.22836 m3 * 60 * 60 *24 *365 = 7,201,561 m^3

Runoff

Tabla 2.31. Escorrentía

ESCORRENTÍA - ESTACIONES CUENCA DEL RIO COELLO			
ESTACION	X	Y	Esc. (mm)
LA CASCADA	836888,4	963400,3	123,70
EL RANCHO	855468,2	1003924,2	129,30
EL PALMAR	859161,3	1000230,5	62,60
LAS JUNTAS	861001,6	994696,8	84,70
EL PLACER	868395,6	990997,4	166,00
HDA CUCUANA	840607,5	972611,3	14,60
LAS DELICIAS	840614,5	976298,5	44,80
TOCHE - IBAGUE	851744,5	991026,3	15,80
LA ESMERALDA	872092,8	989148,1	34,60
CAJAMARCA	849880,7	983655,5	77,90
EL DARIEN	864686,2	985473,2	179,20
HDA PALO GRANDE	851711,3	972590,9	69,90
PASTALES	864695,4	991003,5	133,30
EL SECRETO	866542,5	989157,0	69,50
ROVIRA 2	870199,6	961499,8	4,90
APTO PERALES	881332,4	981760,6	3,60
PERALES HATO OPIA	890583,3	981747,7	0,00
BUENOS AIRES	888718,3	970690,3	0,00
EL ACEITUNO	892423,9	974372,1	0,00
CHICORAL	897957,0	959619,0	0,00
NATAIMA	903502,6	954082,9	0,00
APTO. SANTIAGO VILA	920168,9	965125,1	0,00

N+1

La Colosa: from Anglogold Ashanti, 2015: 0.5 m^3/s = 0.5*60*60*24*365 = 15,768,000 m^3 . La Colosa is projected to recycle 60% of their water; 15,768,000 * .6 = 9,460,000
15,768,000 – 9,460,000 = 6,308,000 m^3 of new water per year.

Surface Water: Refer to table 2.33 under heading “Ecological flow requirement”
- Includes Q.Guala, Q. Chorros Blancos, Q. Espejo, Rio Bermellon 1, Rio Bermellon 2 = 3.39655 m3/second * 60 * 60 * 24 * 365 = 107, 113,600.8 m^3 = 107 Mm^3.

Available water =

60% recycled water from the mine: 9.5 Mm^3 + Surface water: 107 Mm^3 = 116.5 Mm^3

N-1

Urban & Rural Domestic, Livestock

Numbers are in Mm^3

CUENCA	SUBCUENCA	MICROCUENCA	DEMANDA CONSUMO HUMANO Y BOVINO					
			CENSO		CONSUMO HUMANO MMC		GANADO	
			URBANO	RURAL	URBANO	RURAL	CABEZAS	DEMANDA
SUBTOTAL RIO COELLO			**0**	**1357**	**0,000**	**0,059**	**1776**	**0,026**
		Q. Perales		21	0,000	0,001	138	0,00
	Q. Guala			207	0,000	0,009	698	0,01
	Q. Chorros Blancos	Q. El Rincón		116	0,000	0,005	138	0,00
		Q. Chorros Blancos 2	1388	284	0,086	0,012	222	0,00
	TOTAL Q. CHORROS BLANCOS		**1388**	**400**	**0,086**	**0,018**	**361**	**0,005**
		Q. Espejo	4505	280	0,280	0,012	40	0,00
	Río Bermellon 1			129	0,000	0,006	863	0,01
	Río Bermellon 2		1546	580	0,096	0,025	656	0,01

N-2

Campesino Agriculture:

Numbers are in Mm^3

Raw Data:

CUENCA	SUBCUENCA	MICROCUENCA	DEMANDA AGRICOLA											
			CAFÉ Y OTROS		ARROZ		HORTALIZAS		FRUTALES		SORGO		ALGODÓN	
			HECT.	DEMANDA	HECT.	DEMANDA	HECT.	DEMANDA	HECT.	DEMANDA	HECT.	DEMANDA	HECT.	DEMANDA
SUBTOTAL RIO COELLO			**410,46**	**4,926**	**0,00**	**0,000**	**125,40**	**1,451**	**40,99**	**0,395**	**0,00**	**0,000**	**0,00**	**0,000**
		Q. Perales	0,00	0,00	0,00		51,31	0,406	0,00		0,00		0,00	
	Q. Guala		0,99	0,01	0,00		171,68	1,622	0,00		0,00		0,00	
	Q. Chorros Blancos	Q. El Rincón	17,59	0,21	0,00		1,29	0,012	0,00		0,00		0,00	
		Q. Chorros Blancos 2	44,00	0,53	0,00		100,43	0,925	4,16	0,033	0,00		0,00	
	TOTAL Q. CHORROS BLANCOS		**61,59**	**0,739**	**0,00**	**0,000**	**101,71**	**0,936**	**4,16**	**0,033**	**0,00**	**0,000**	**0,00**	**0,000**
		Q. Espejo	93,21	1,12	0,00		104,16	0,959	0,19	0,001	0,00		0,00	
	Río Bermellon 1		0,00	0,00	0,00		123,23	1,229	0,00		0,00		0,00	
	Río Bermellon 2		35,86	0,43	0,00		397,64	4,994	59,03	0,643	0,00		0,00	

Cultivo	ha	Demand (Mm3)	m^3/ha	Jornales		Hours of paid Labour	m3/ Hour of paid labour
Coffee	191.65	2.3		211 (per ha)	211*191.65	?	?
Rice	0	0					
Vegetables	949.73	10.146					
Sugar Cane				236			
Peanut				15			
Corn				45			
Arracacha				116			
Fruit	63.38	0.677					
Ciruela				109			
Sorgum	0	0					
Cotton	0	0		130			
Total	1204.76	13.123	10892.63				
		13,123,000					

1 coffee numbers only include washing coffee, as it requires no irrigation

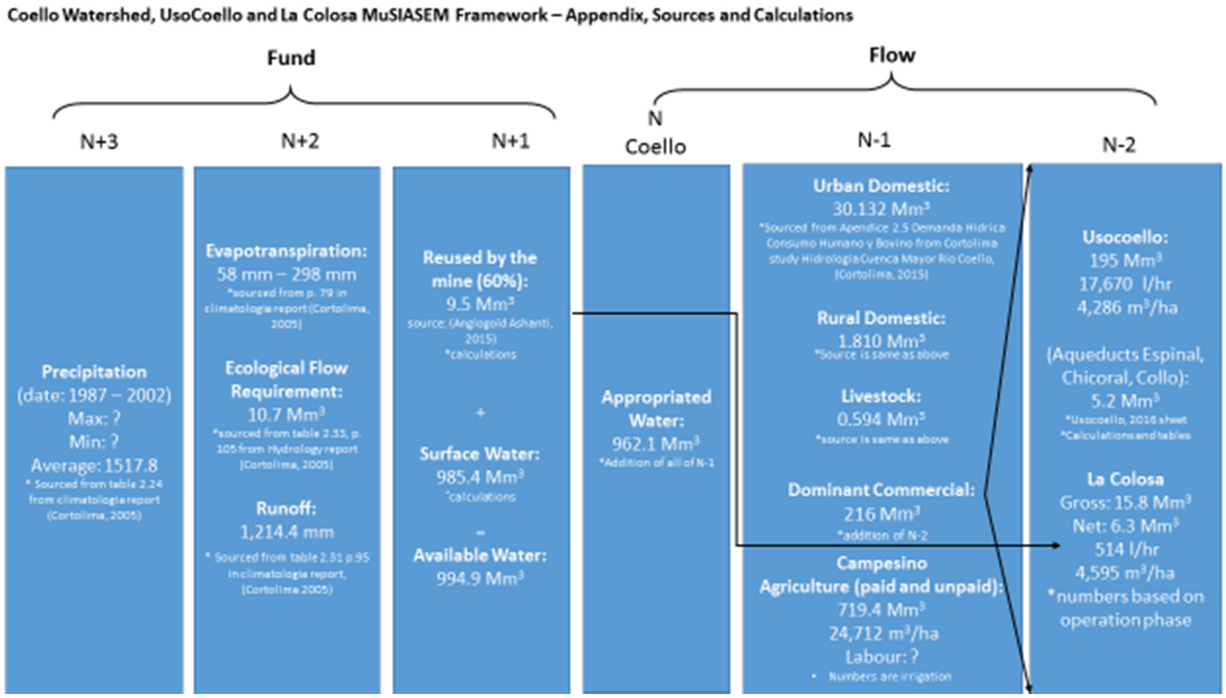
2 numbers are irrigation numbers, not crop water requirements

La Colosa:

	Ha [3]	Unit/s [1]	m3 (daily)	m3 (annual)	Reused water	Water usage (annu	m3/ha	Number of jobs (Annual) [4]	hour of labour [5]	m3/hour of labour
	1,400									
Exploration phase [2]		L per s = 4	(.004*86400) = 345.6	(345.6 * 365) = 126,144	na	126,144	90	1,000	2,000,000	0.063072
Production phase 60%		m3 per s = 0.5	(0.5*86400) = 43200	43200 * 365) = 15,768,000	60% recirculated	6,307,200	4,505	7,000	14,000,000	0.450514286
								1,500 direct		
								5,000 indirect		
Total						6,433,344	4,595		16,000,000	0.513586286
Production phase 100%				15,768,000			11263		14,000,000	1.126285714

1 Source: Anglogold Ashanti, 2013
2 Exploration phase is from 2007 – 2018 (Anglogold Ashanti, 2015)
3 (Anglogold Ashanti, 2015)
4 (Anglogold Ashanti, 2015)
5 Assumption that people work an average of 40 hours per week, 50 weeks a year
6 Information for the water use for other phases is currently unavailable

Appendix E: Coello Framework Raw Data, Sources and Calculations



N+3

Total Precipitation

Tabla 2.24. Precipitación Total

PRECIPITACIÓN MEDIA ESTACIONES CUENCA MAYOR RIO COELLO 1987 – 2002																
EST. N°	ESTACION	X	Y	PreMe. En	PreMe. Feb	PreMe Mar	PreMe .Abr	PreMe .May	PreMe .Jun	PreMe .Jul	PreMe . Agt	PreMe . Sept	PreMe .Oct	PreMe .Nov	PreMe .Dic	PreMe. Tot
1	LA CASCADA	836888,4	963400,3	65,1	73,5	114,1	124,9	144,0	111,1	98,3	109,8	119,8	128,4	135,4	99,0	**1323,3**
2	EL RANCHO	855468,2	1003924,2	41,9	51,9	121,7	162,9	187,8	144,7	138,7	146,7	163,1	151,2	99,3	82,1	**1491,8**
3	EL PALMAR	859161,3	1000230,5	45,5	60,6	100,6	148,9	162,2	131,4	101,6	105,6	156,0	134,4	108,7	61,8	**1317,4**
4	LAS JUNTAS	861001,6	994696,8	50,2	68,5	108,6	157,4	166,7	128,1	140,6	126,2	180,7	148,8	107,0	67,2	**1450,1**
5	EL PLACER	868395,6	990997,4	86,7	94,1	181,3	236,6	200,4	179,2	161,3	146,9	236,3	194,0	138,1	99,0	**1953,8**
6	HDA CUCUANA	840607,5	972611,3	44,3	57,6	100,5	137,5	140,0	96,6	84,2	55,9	102,0	108,4	90,7	57,0	**1074,5**
7	LAS DELICIAS	840614,5	976298,5	52,7	56,9	89,5	150,4	195,2	128,2	96,5	79,3	138,9	117,2	100,7	79,1	**1284,6**
8	TOCHE – IBAGUE	851744,5	991026,3	51,5	64,6	74,4	157,7	127,2	104,5	89,6	74,4	131,7	96,9	81,8	59,0	**1113,2**
9	LA ESMERALDA	872092,8	989148,1	53,2	66,6	104,9	151,6	166,3	130,5	107,8	77,8	137,0	117,7	87,4	71,5	**1272,3**
10	CAJAMARCA	849880,7	983655,5	126,4	119,9	149,7	183,8	175,6	93,2	81,5	97,0	184,4	148,6	140,9	92,9	**1557,9**
11	EL DARIEN	864686,2	985473,2	113,1	134,2	198,1	298,0	265,1	174,6	155,8	122,8	231,4	205,4	164,1	123,3	**2185,7**
12	HDA PALO GRANDE	851711,3	972590,9	69,2	94,2	145,1	220,9	202,8	144,6	125,1	107,5	160,3	157,2	127,0	86,0	**1639,8**
13	PASTALES	864695,4	991003,5	86,5	116,0	204,9	287,6	236,2	182,5	182,1	139,4	264,2	221,9	196,3	113,7	**2231,1**
14	EL SECRETO	866542,5	989157,0	82,3	107,1	159,5	247,5	212,9	154,1	132,7	127,2	203,7	182,7	141,4	100,5	**1852,2**
15	ROVIRA 2	870199,6	961499,8	90,0	110,6	169,2	203,2	179,9	125,9	82,7	70,2	173,3	210,6	202,9	115,2	**1733,6**
16	APTO PERALES	881332,4	981760,6	81,5	119,0	141,2	205,5	217,8	119,1	79,7	76,2	158,6	194,5	147,5	94,9	**1635,6**
17	PERALES HATO OPIA	890583,3	981747,7	65,8	68,5	117,4	186,7	197,3	96,6	82,3	66,7	154,2	122,9	114,7	76,7	**1349,8**
18	BUENOS AIRES	888718,3	970690,3	55,3	72,1	134,2	207,2	193,6	107,8	70,2	56,0	147,0	194,0	120,8	95,7	**1457,9**
19	EL ACEITUNO	892423,9	974372,1	45,2	70,8	104,0	197,2	206,4	102,3	66,6	64,8	157,4	158,9	105,9	78,1	**1357,5**
20	CHICORAL	897957,0	959619,0	48,7	76,6	161,9	186,9	182,0	89,2	73,4	61,6	121,6	187,6	139,4	87,0	**1416,1**
21	NATAIMA	903502,6	954082,9	73,4	102,9	189,2	158,7	176,6	93,2	52,7	51,6	183,5	188,9	146,1	101,4	**1518,3**
22	APTO. SANTIAGO VILA	920168,9	965125,1	39,6	98,5	121,2	145,7	130,6	72,6	36,1	32,8	130,9	168,7	107,0	90,2	**1174,0**
Valor Promedio de la Serie 1987 - 2002				**66,7**	**85,7**	**136,0**	**188,9**	**184,8**	**123,2**	**101,8**	**90,7**	**165,3**	**160,9**	**127,4**	**87,8**	**1517,8**

N+2

Ecological Flow Requirement:

CUENCA	SUBCUENCA	MICROCUENCA	Precip. Max. Diaria		CAUDAL MEDIO (m3/seg)	CAUDAL DE REPARTO (m3/seg)	Q. ECOLOGICO (m3/seg)	Oferta Hídrica Neta (m3/seg)
			Vr. Med	Vr. Mín.				
		Q. Salada	90,32	60,05	0,00203	0,00135	0,00034	0,00169
		Q. Chaguala 6	94,30	58,10	0,01443	0,00889	0,00222	0,01221
		Zanja la Moronga	90,32	60,05	0,00118	0,00078	0,00020	0,00098
		Q. Leona	94,30	58,10	0,02841	0,01751	0,00438	0,02404
		Q. La Jabonera	94,30	58,10	0,01582	0,00975	0,00244	0,01338
		Q. Quindia	94,30	58,10	0,00000	0,00000	0,00000	0,00000
		Q. Chaguala 7	88,03	54,37	0,00000	0,00000	0,00000	0,00000
	TOTAL Q. CHAGUALA				0,06426		0,00994	0,05432
SUBTOTAL RIO COELLO					0,42664		0,05915	0,36749
TOTAL RIO COELLO					5,55223		0,33872	5,21352
TOTAL CUENCA MAYOR RIO COELLO					31,24756		0,33872	30,90884

Runoff: Refer to runoff section in Appendix D for raw data.

N+1

Surface water:

CUENCA	SUBCUENCA	MICROCUENCA	Precip. Max. Diaria		CAUDAL MEDIO (m3/seg)	CAUDAL DE REPARTO (m3/seg)	Q. ECOLOGICO (m3/seg)	Oferta Hídrica Neta (m3/seg)
			Vr. Med	Vr. Mín.				
		Q. Salada	90,32	60,05	0,00203	0,00135	0,00034	0,00169
		Q. Chaguala 6	94,30	58,10	0,01443	0,00889	0,00222	0,01221
		Zanja la Moronga	90,32	60,05	0,00118	0,00078	0,00020	0,00098
		Q. Leona	94,30	58,10	0,02841	0,01751	0,00438	0,02404
		Q. La Jabonera	94,30	58,10	0,01582	0,00975	0,00244	0,01338
		Q. Quindia	94,30	58,10	0,00000	0,00000	0,00000	0,00000
		Q. Chaguala 7	88,03	54,37	0,00000	0,00000	0,00000	0,00000
	TOTAL Q. CHAGUALA				0,06426		0,00994	0,05432
SUBTOTAL RIO COELLO					0,42664		0,05915	0,36749
TOTAL RIO COELLO					5,55223		0,33872	5,21352
TOTAL CUENCA MAYOR RIO COELLO					31,24756		0,33872	30,90884

31.24756 *60*60*24*365 = 985,423,052 Mm^3

N-1

Urban & Rural Domestic, Livestock:

CUENCA	SUBCUENCA	MICROCUENCA	DEMANDA CONSUMO HUMANO Y BOVINO					
			CENSO		CONSUMO HUMANO MMC		GANADO	
			URBANO	RURAL	URBANO	RURAL	CABEZAS	DEMANDA
		Q. Chaguala 4		8	0,000	0,000	56	0,00
		Q. Chaguala 5		44	0,000	0,002	199	0,00
		Q. Cunira		158	0,000	0,007	232	0,00
		Q. Chicuambe		19	0,000	0,001	67	0,00
		Q. Salada		248	0,000	0,011	177	0,00
		Q. Chaguala 6		29	0,000	0,001	9	0,00
		Zanja la Moronga		143	0,000	0,006	109	0,00
		Q. Leona		20	0,000	0,001	36	0,00
		Q. La Jabonera		13	0,000	0,001	28	0,00
		Q. Quindia		12	0,000	0,001	31	0,00
		Q. Chaguala 7		171	0,000	0,008	174	0,00
	TOTAL Q. CHAGUALA		0	1477	0,000	0,065	4439	0,065
SUBTOTAL RIO COELLO			56347	4445	3,496	0,195	8821	0,129
Ajuste Otras Áreas del Distrito Beneficiadas								
TOTAL CUENCA MAYOR RIO COELLO			485601	41317	30,132	1,810	40653	0,594

Campesino Agriculture:

CUENCA	SUBCUENCA	MICROCUENCA	DEMANDA AGRICOLA											
			CAFÉ Y OTROS		ARROZ		HORTALIZAS		FRUTALES		SORGO		ALGODÓN	
			HECT.	DEMANDA	HECT.	DEMANDA	HECT	DEMANDA	HECT.	DEMANDA	HECT.	DEMANDA	HECT.	DEMANDA
		Q. San Lorenzo	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. Chaguala 4	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. Chaguala 5	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. Cunira	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. Chicuambe	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. Salada	0,00	0,00	0,00		0,00		5,61	0,167	0,00		0,00	
		Q. Chaguala 6	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Zanja la Moronga	0,00	0,00	0,00		0,00		5,50	0,163	0,00		0,00	
		Q. Leona	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. La Jabonera	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. Quindia	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
		Q. Chaguala 7	0,00	0,00	0,00		0,00		0,00		0,00		0,00	
	TOTAL Q. CHAGUALA		0,00	0,000	0,00	0,000	0,00	0,000	36,55	0,994	0,00	0,000	0,00	0,000
SUBTOTAL RIO COELLO			0,000	0,000	1518,4	66,719	0,000	0,000	359,80	9,758	329,27	10,648	132,99	4,334
Ajuste Otras Áreas del Distrito Beneficiadas					6603,0	279,896								
TOTAL CUENCA MAYOR RIO COELLO			6952,98	83,436	12103,37	500,036	6490,55	73,496	2849,11	40,662	581,6	17,415	132,99	4,334

Crop	Ha	Water Demand (Mm3) from table 2.6 in appendix	m3/ha for first (from table 2.6 in Appendix)
Café and others	6952.98	83.436	
Rice	12103.37	500.036	
Hortalizas	6490.55	73.496	
Fruit	2849.11	40.662	
Sorgum	581.6	17.415	
Cotton	132.99	4.334	
Total	29110.6	719.379	0.0247

1 coffee does not need water for irrigation, numbers are for washing only

N-2
UsoCoello (refer to Appendix B for raw data)

1 (personal communication with UsoCoello)
2 Sourced from Usocoello sheet (Appendix X)
3 Sourced from Appendix X – Aforos y Precipitacion from UsoCoello
4 Water use per semester includes both annual and perennial crops
5 semester A and Semester B use different plots per crop; there is no double cropping

USOCOELLO HAS 9.64 m3/sec of water concessioned from Rio Coello. = 304,007,040 m3, 304 Mm^3

UsoCoello has 10.91 m3/sec of water concessioned from Rio Cucuana: *60*60*24*365 = 344,057,760 m3, 344 Mm^3

304,007,040 + 344, 057,760 = 648,064,800

304,007,040/648,064,800 = 0.47

0.47 * 414.9 = 195.003 of irrigation comes from Coello

.53 * 414.9 = 219.897 of irrigation comes from Cucuana

UsoCoello has concessions from the Cucuana River (344 Mm3), and the Coello River (304 Mm3), meaning that the Coello River accounts for 47% of water usage in UsoCoello (assuming UsoCoello is not using more water than is concessioned). UsoCoello also gives a total of 11 Mm3 of water to the aqueducts Espinal, Chicoral and Coello per year. Therefore, 5.2 Mm3 of water given to the aqueducts

0.35 m3/s given to acueducts Espinal, Chicoral and Coello: 11,037,600 + 414,900,000 = 425,937,600 = 425.9 Mm3.

Appendix F – Jornales

Agricultural labour in Colombia is measured by “jornales.” One jornale is an eight hour work day.

The data acquired from Anglogold Ashanti indicated that the operation phase of La Colosa would generate 7,000 jobs overall (5,500 indirect employees, 1,500 direct employees). It was assumed that both indirect and direct employees would work an average of 40 hours per week, 50 weeks per year.

Appendix G – raw data from UsoCoello Aforos y Precipitacion

PROMEDIOS HISTORICOS DE PRECIPITACIÓN EN EL DISTRITO DE RIEGO DE LOS RIOS COELLO Y CUCUANA "USOCOELLO"

AÑOS	ENERO	FEBRERO	MARZO	ABRIL	MAYO	JUNIO	JULIIO	AGOSTO	SEPTIEMB	OCTUBRE	NOVIEMBI	DICIEMBR	TOTAL	PROMEDIC
2004	54.2	124.7	31.9	241.2	222.4	51.8	40.3	39.3	121.8	336.0	88.4	62.3	1414.2	117.8
2005	84.3	46.0	158.1	68.6	299.8	76.9	21.3	14.4	110.9	266.9	261.2	102.9	1511.5	126.0
2006	121.5	38.6	182.4	200.1	204.8	61.8	25.9	8.7	130.2	91.3	199.3	191.5	1456.3	121.4
2007	97.5	2.0	219.0	382.7	272.6	66.7	105.8	42.5	34.5	322.2	185.8	77.5	1808.9	150.7
2008	101.2	76.5	103.8	196.5	261.4	122.0	92.3	229.9	153.7	183.3	190.7	42.6	1753.8	146.2
2009	175.4	107.1	226.5	110.6	121.9	66.1	2.4	38.6	106.3	50.6	116.2	190.9	1312.6	109.4
2010	74.2	48.9	61.5	571.2	286.7	128.7	239.4	53.2	150.7	84.7	136.4	90.0	1925.5	160.5
2011	121.6	133.2	144.8	322.1	119.3	83.4	43.2	41.6	106.5	104.7	168.9	119.2	1508.6	125.7
2012	65.1	88.3	171.6	171.5	53.3	6.3	41.0	5.9	15.5	211.6	125.8	55.3	1011.2	84.3
2013	53.0	158.2	126.0	126.0	349.4	84.7	48.2	43.2	49.7	145.4	98.6	125.3	1407.6	117.3
2014	93.1	93.1	62.9	376.1	244.7	95.3	0.0	0.0	0.0	0.0	0.0	0.0	965.3	80.4
Averages	94.6	83.3	135.3	251.5	221.5	76.7	60.0	47.0	89.1	163.3	142.8	96.1	1461.4	
Precipitation Semester A	863.0													
Precipitation Semester B	598.4													
COMISIÓN DE AFOROS														

Appendix H – Weather stations in UsoCoello