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LLNL-TR-475772

Estimated Water Flows in 2005: United States

C. A. Smith, R. D. Belles, A. J. Simon

March 24, 2011

Disclaimer

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United States

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Clara A. Smith, A.J. Simon, Rich Belles
Lawrence Livermore National Laboratory

Abstract

Flow charts depicting water use in the United States have been constructed from publicly available data and estimates of water use patterns. Approximately 410,500 million gallons per day of water are managed throughout the United States for use in farming, power production, residential, commercial, and industrial applications. Water is obtained from four major resource classes: fresh surface-water, saline (ocean) surface-water, fresh groundwater and saline (brackish) groundwater. Water that is not consumed or evaporated during its use is returned to surface bodies of water. The flow patterns are represented in a compact "visual atlas" of 52 state-level (all 50 states in addition to Puerto Rico and the Virgin Islands) and one national water flow chart representing a comprehensive systems view of national water resources, use, and disposition.

Introduction

Lawrence Livermore National Lab (LLNL) has published flow charts (also referred to as "Sankey Diagrams") of important national commodities since the early 1970s. The most widely recognized of these charts is the U.S. energy flow chart (http://flowcharts.llnl.gov). LLNL has also published charts depicting carbon (or carbon dioxide potential) flow and water flow at the national level as well as energy, carbon, and water flows at the international, state, municipal, and organizational (i.e. United States Air Force) level. Flow charts are valuable as single-page references that contain quantitative data about resource, commodity, and byproduct flows in a graphical form that also convey structural information about the system that manages those flows.

LLNL previously produced flow charts depicting water use for the U.S. as a whole from 1995 and 2000 data. Data on water use is compiled by the U.S. Geological Survey (USGS) every five years, and is released between 3 to 4 years after the data collection year. Data for 2005 (Kenny *et. al.*, 2009) was released in October of 2009. This is the first presentation of a comprehensive state-level package of water flow charts for the United States.

Water use data is notoriously hard to compile. Accounting policies vary between different water management districts and water use is not metered in the same way that higher-priced commodities are sold. Quantifying water use by location and sector requires substantial estimation.

Water disposition is even more difficult to quantify. While the quality of wastewater discharge is measured regularly for environmental purposes, the total quantity of wastewater is not carefully monitored, especially when that wastewater already meets environmental regulations for discharge.

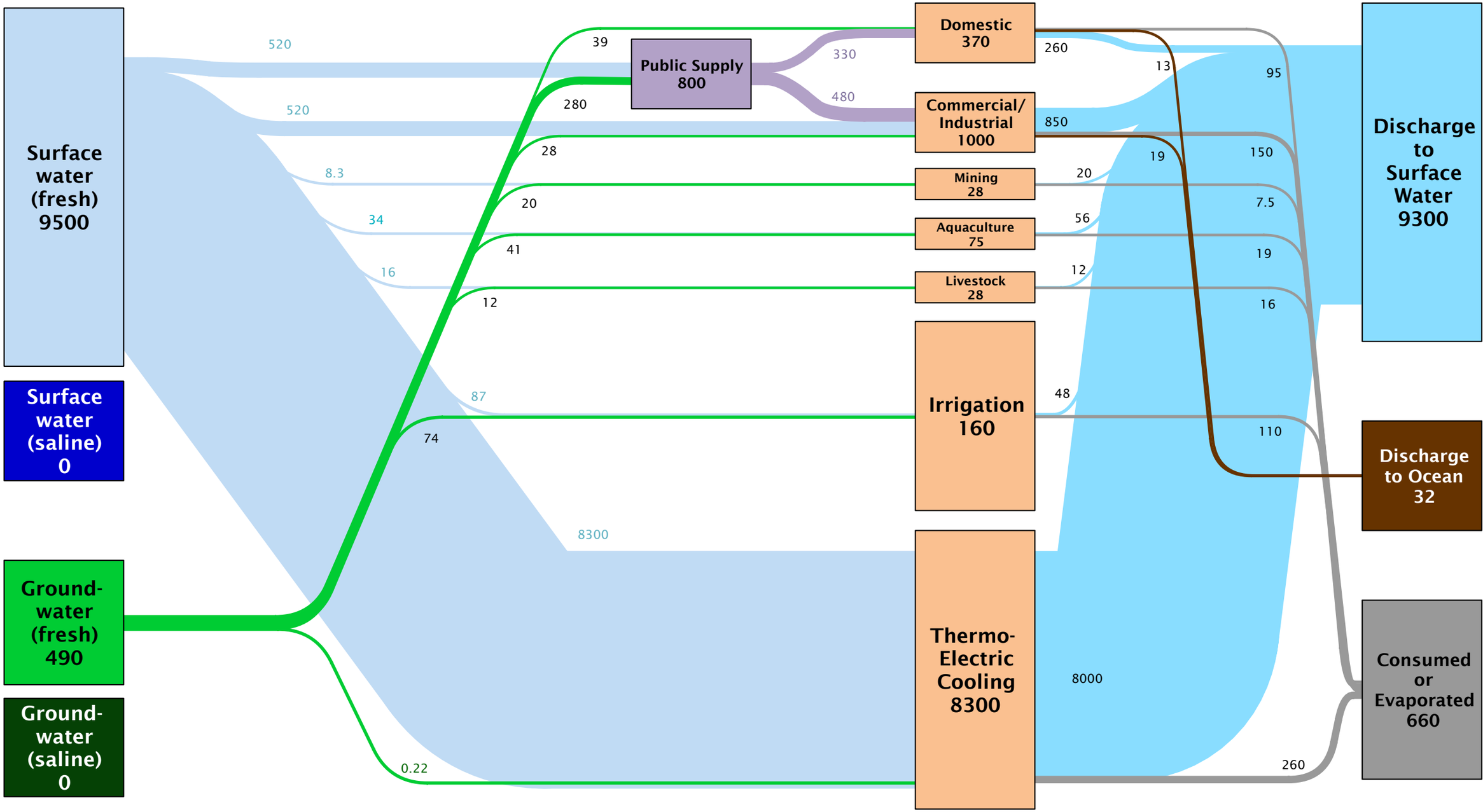
Nonetheless, this report attempts to depict the approximate relative scale of water withdrawal and consumption for various sectors of the economy.

Water is procured for economic purposes from four classes of sources: fresh surface-water, saline (ocean) surface-water, fresh groundwater and saline (brackish) groundwater. Fresh surface-water, from lakes and rivers, is used at large scale in every sector of the economy. Saline surface water, primarily ocean water, is mostly used for once-through thermoelectric cooling, although some ocean water is used for industrial cooling and a small but growing amount of ocean water is being desalinated for public consumption. Significant quantities of fresh groundwater are used in irrigation and fresh groundwater plays an important role in both public supply as well as self-supplied domestic water consumption. Brackish groundwater is the most difficult water resource to use and is therefore primarily used in the mining sector and in power production (often in geothermal power plants).

Per the most recent USGS water use report, the water economy is separated into seven use sectors: Domestic, Commercial/Industrial, Mining, Aquaculture, Livestock, Irrigation, and Thermoelectric Cooling. Public Supply, the management of quality-controlled water networks, plays an intermediate role between water resources and end use. Commercial water is not directly specified in the USGS report, however, the USGS mentions that Public Supply supports commercial and some light industrial operations. For that purpose, the commercial and industrial sectors have been combined in this analysis.

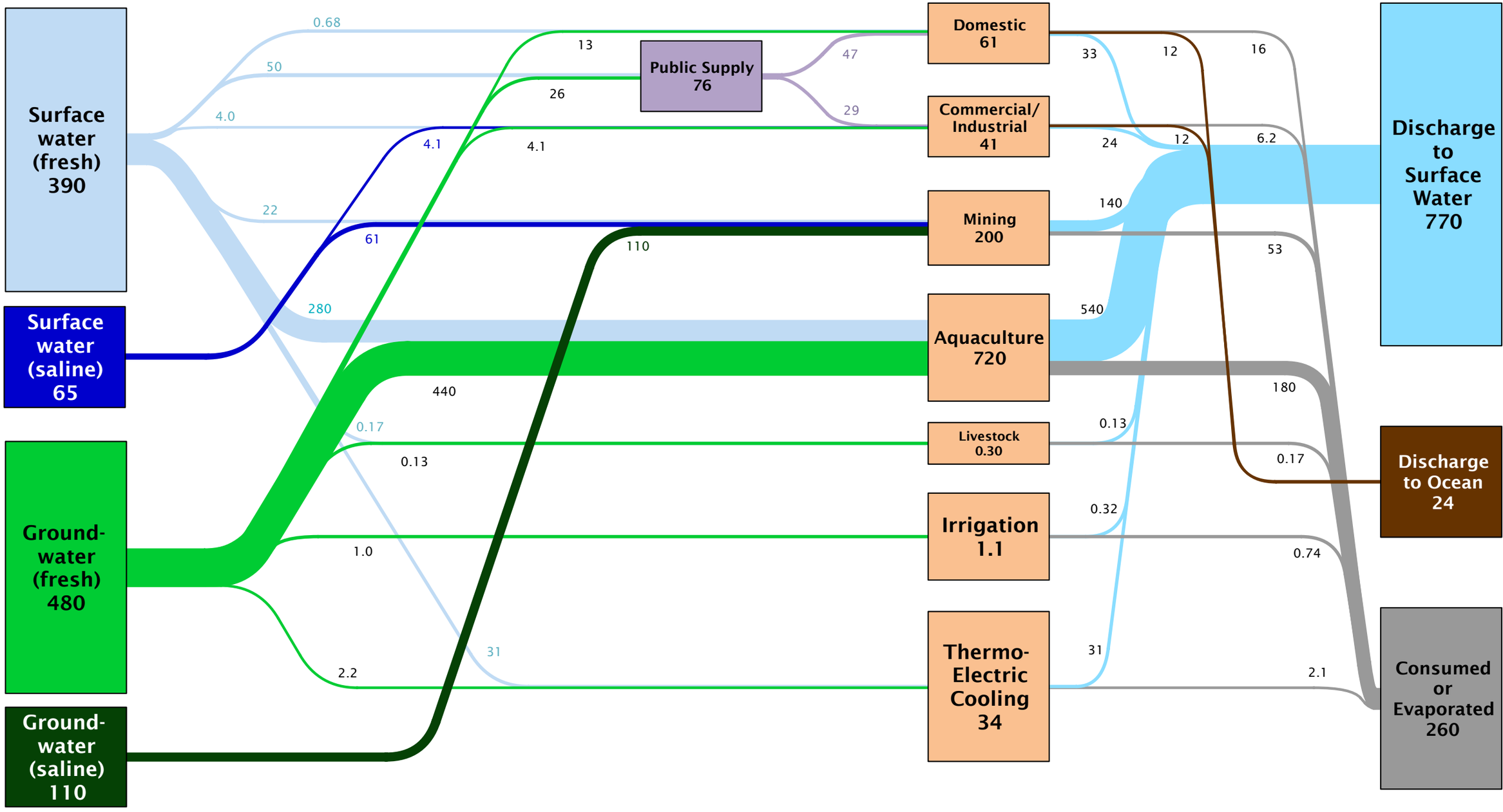
The 2009 USGS report does not describe the disposition of water that has been used by various sectors of the economy. Nonetheless, this analysis attempts to quantify the amount of water consumed by each economic sector. Of the water not consumed, the amount of water returned to surface fresh-water bodies and the amount discharged to the ocean are also approximated. Those quantities are estimated as described in the Analysis section. Water can be consumed (chemically broken down or incorporated into a product) or evaporated from a sector. The majority of consumed/evaporated water eventually rejoins the global hydrologic cycle, but is not assumed to be reintroduced to the surface waters in any particular geographic location. Water that is discharged to surface bodies (lakes or streams) may be available for re-use, depending on its quality, temperature, and location. Water that is discharged to the ocean is no longer available for any purpose except those processes that use saline surface-water.

Estimated Alabama Water Flow in 2005: 10000 Million Gallons/Day



Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Alaska Water Flow in 2005: 1100 Million Gallons/Day



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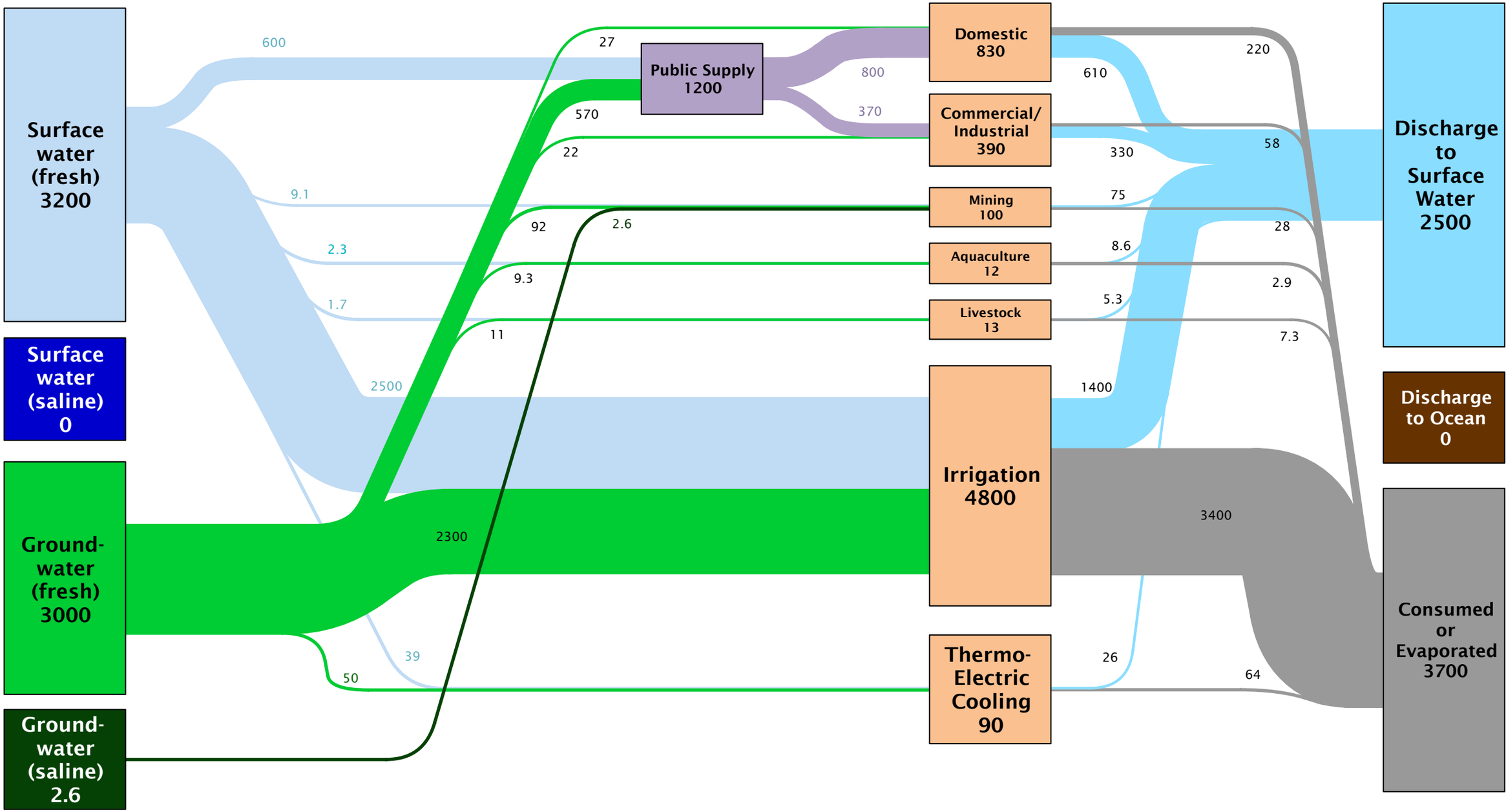
Estimated Arizona Water Flow in 2005: 6200 Million Gallons/Day



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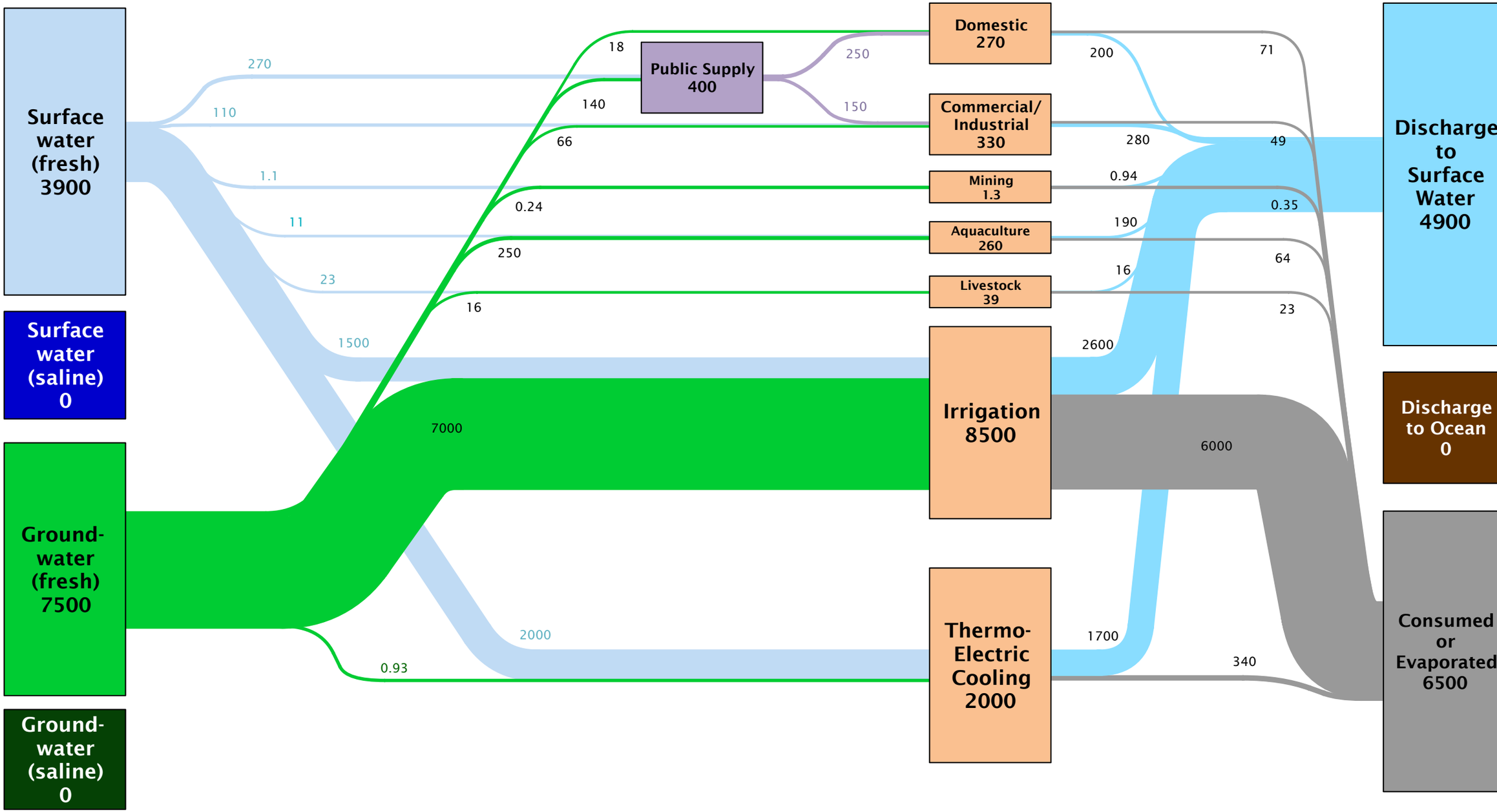
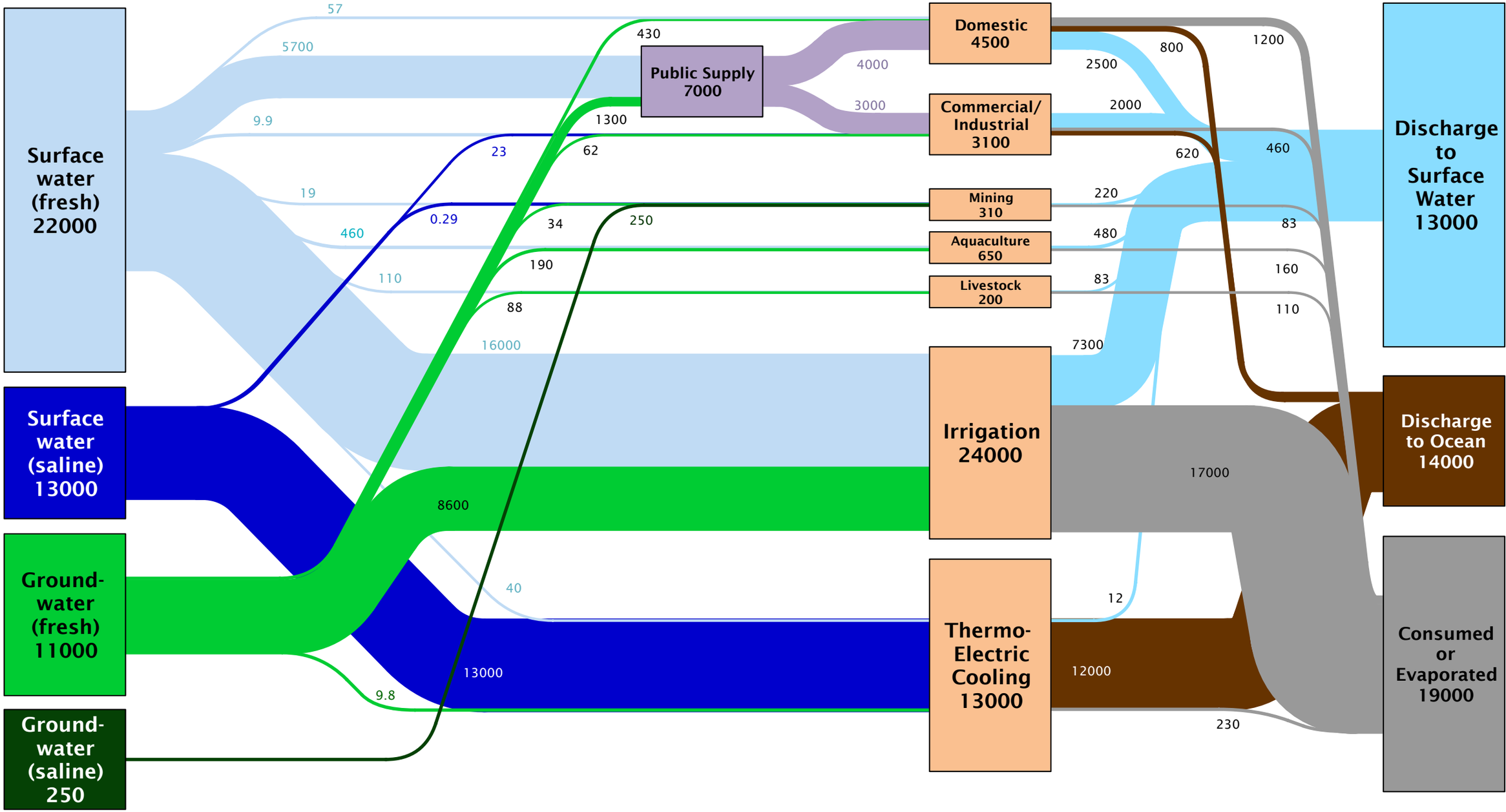
Estimated Arkansas Water Flow in 2005: 11000 Million Gallons/Day



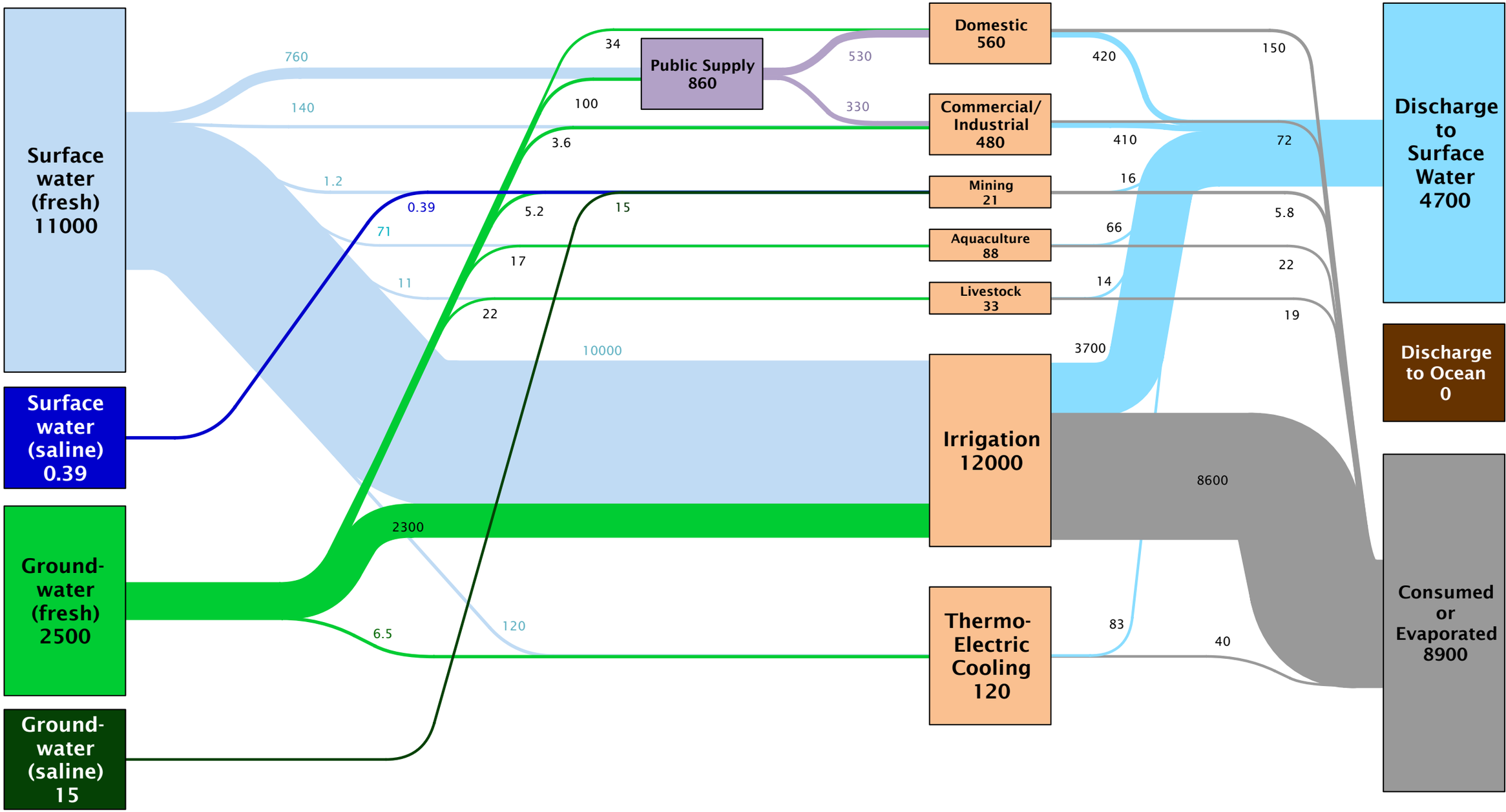
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated California Water Flow in 2005: 46000 Million Gallons/Day



Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Colorado Water Flow in 2005: 14000 Million Gallons/Day



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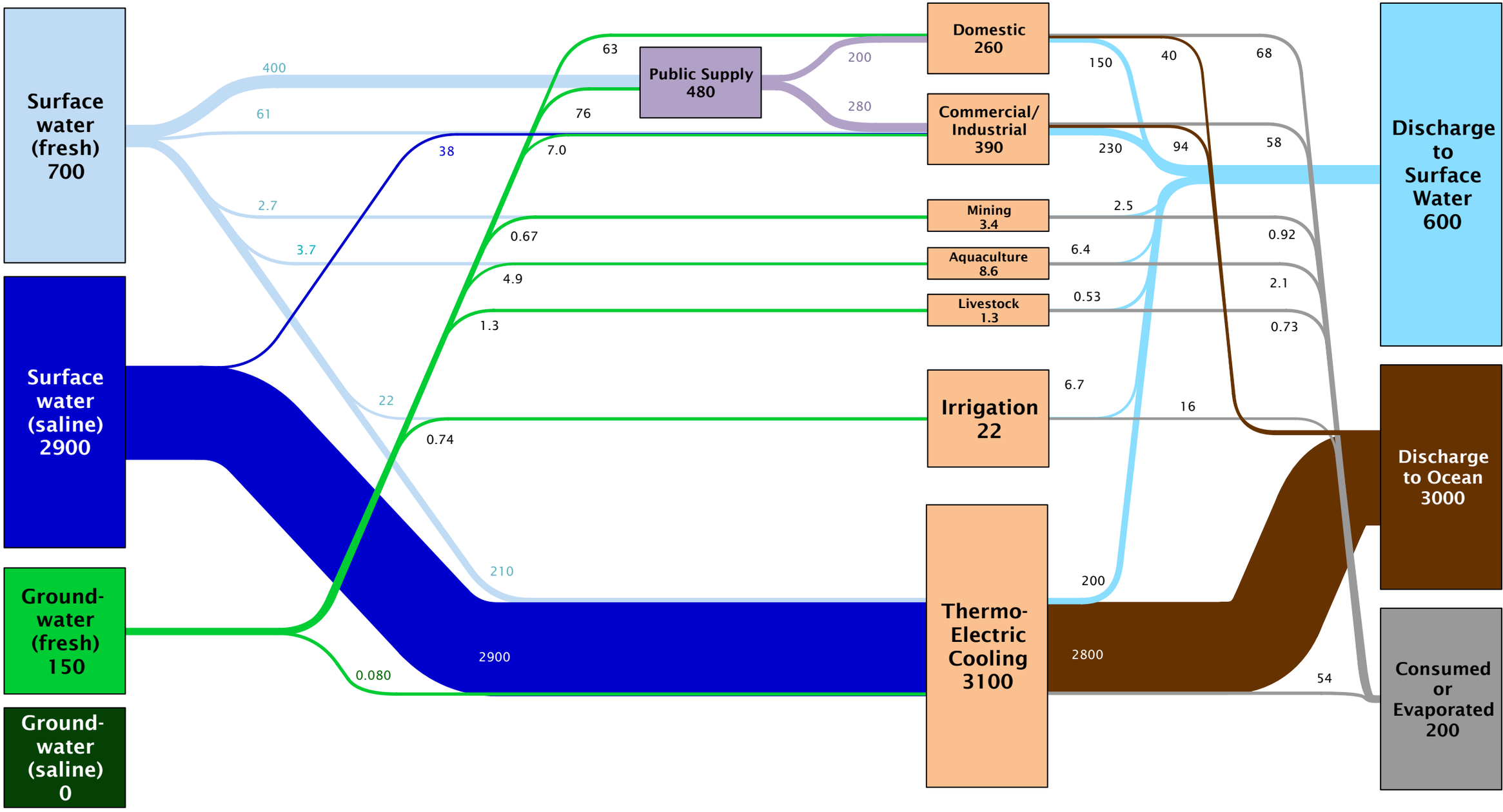
Estimated Connecticut Water Flow in 2005: 3800 Million Gallons/Day



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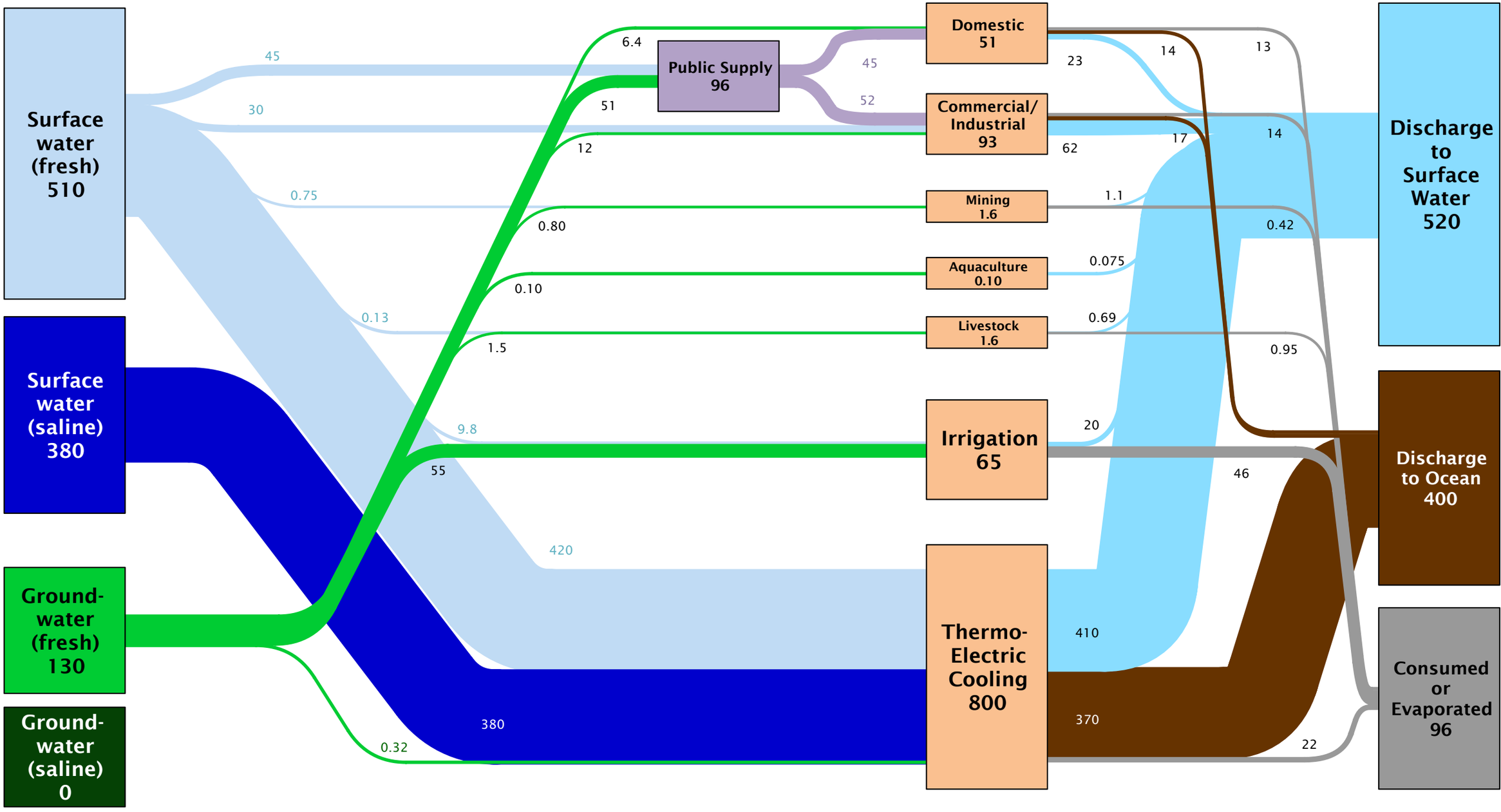
Estimated Delaware Water Flow in 2005: 1000 Million Gallons/Day



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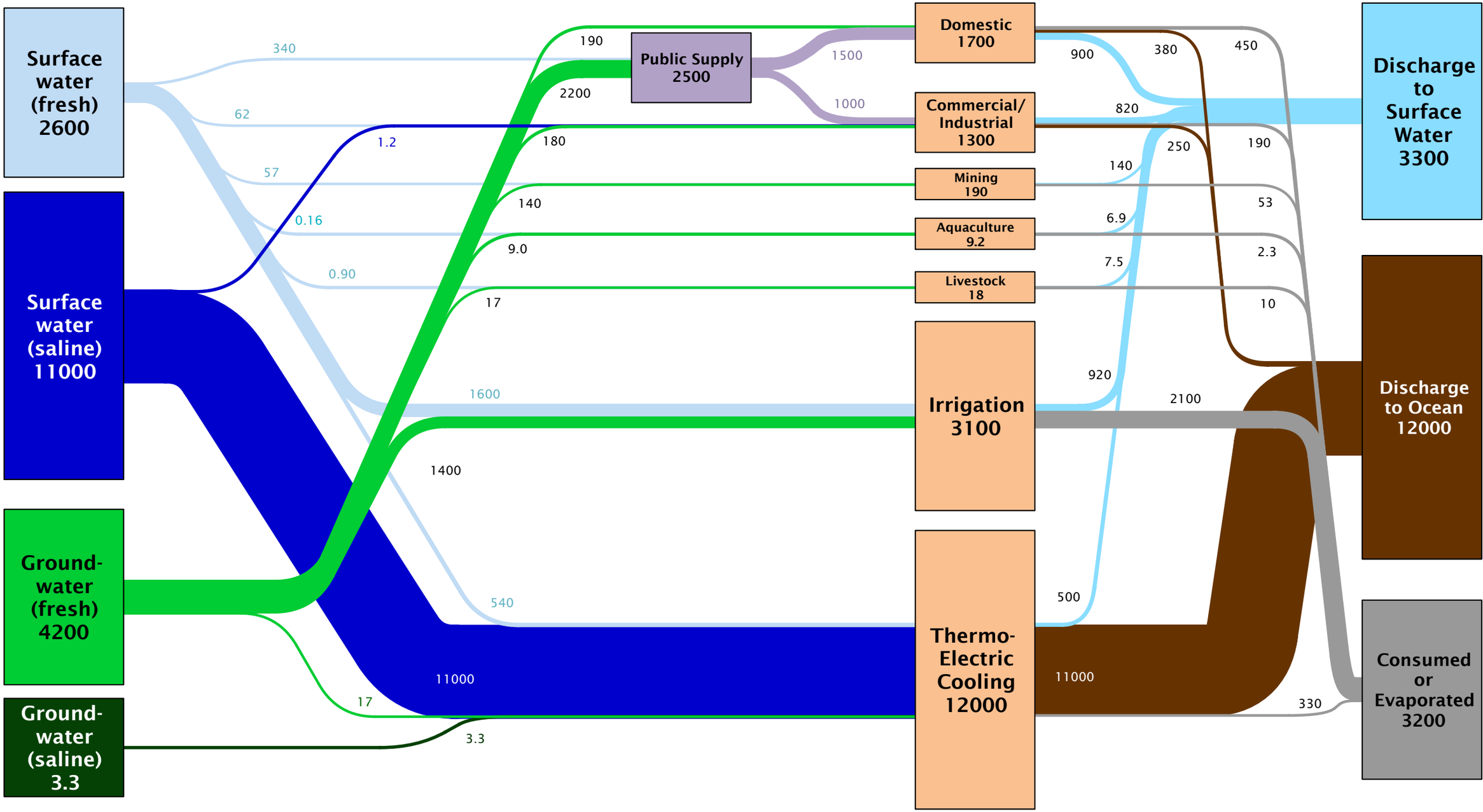
Estimated Florida Water Flow in 2005: 18000 Million Gallons/Day



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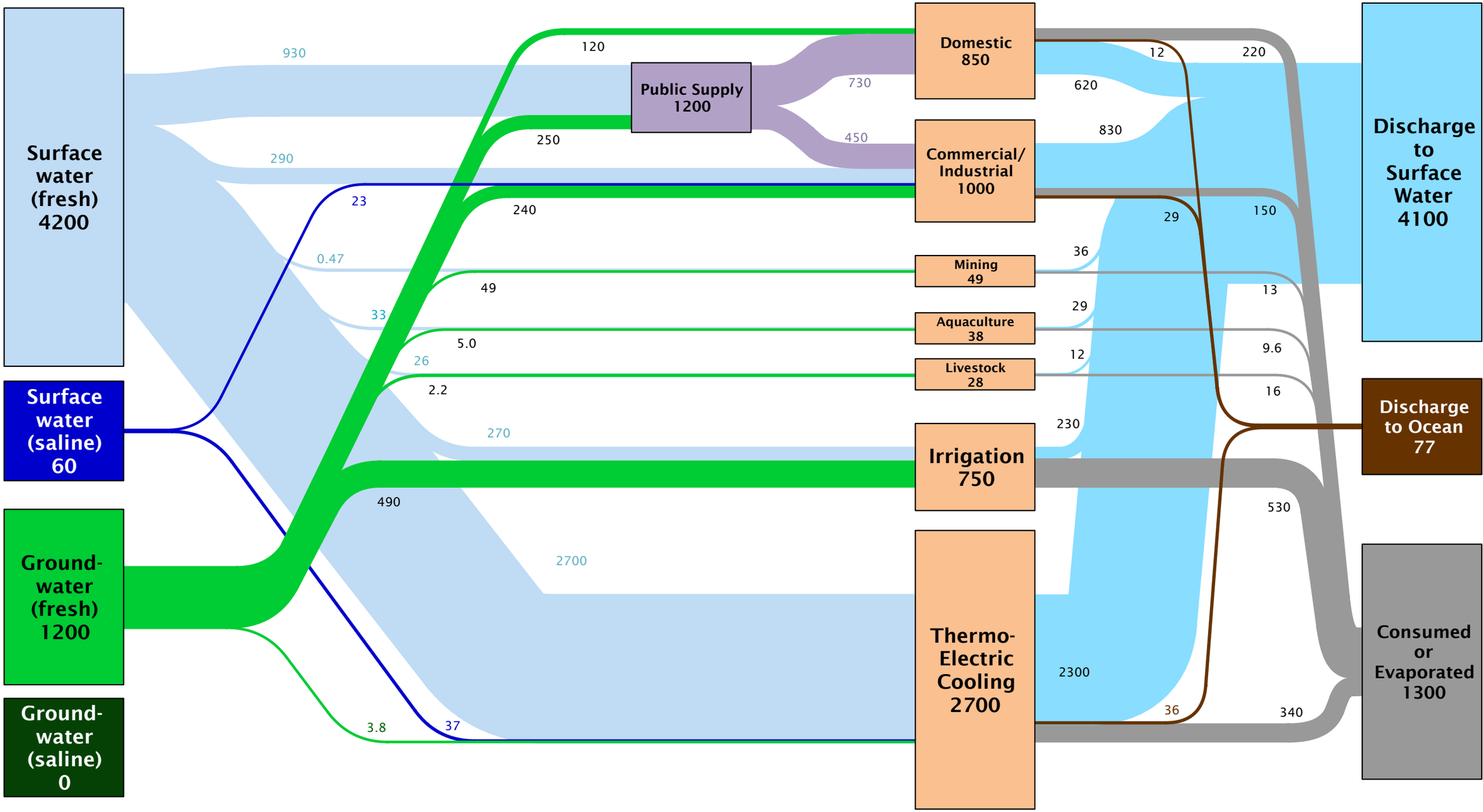
Estimated Georgia Water Flow in 2005: 5400 Million Gallons/Day



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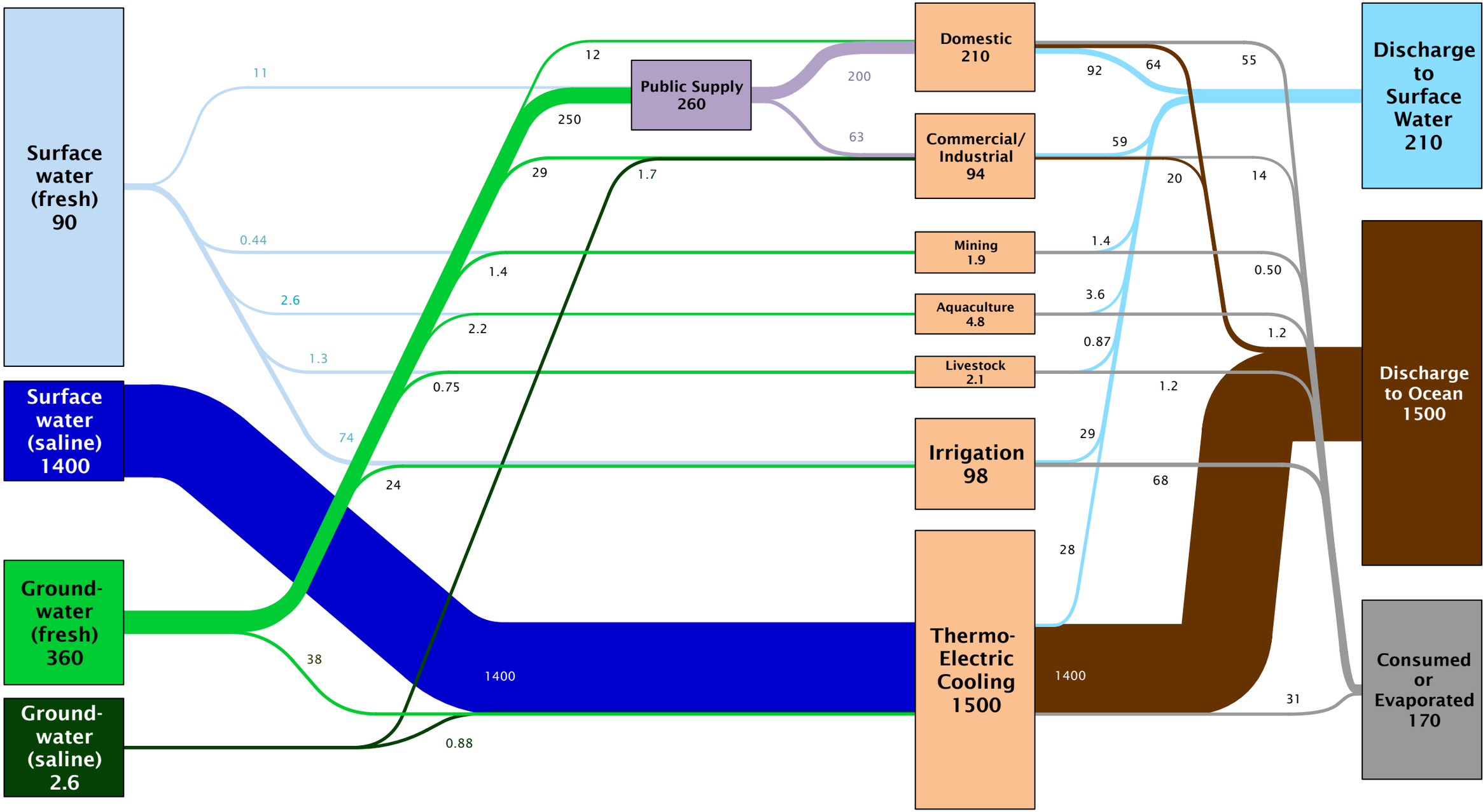
Estimated Hawaii Water Flow in 2005: 1900 Million Gallons/Day



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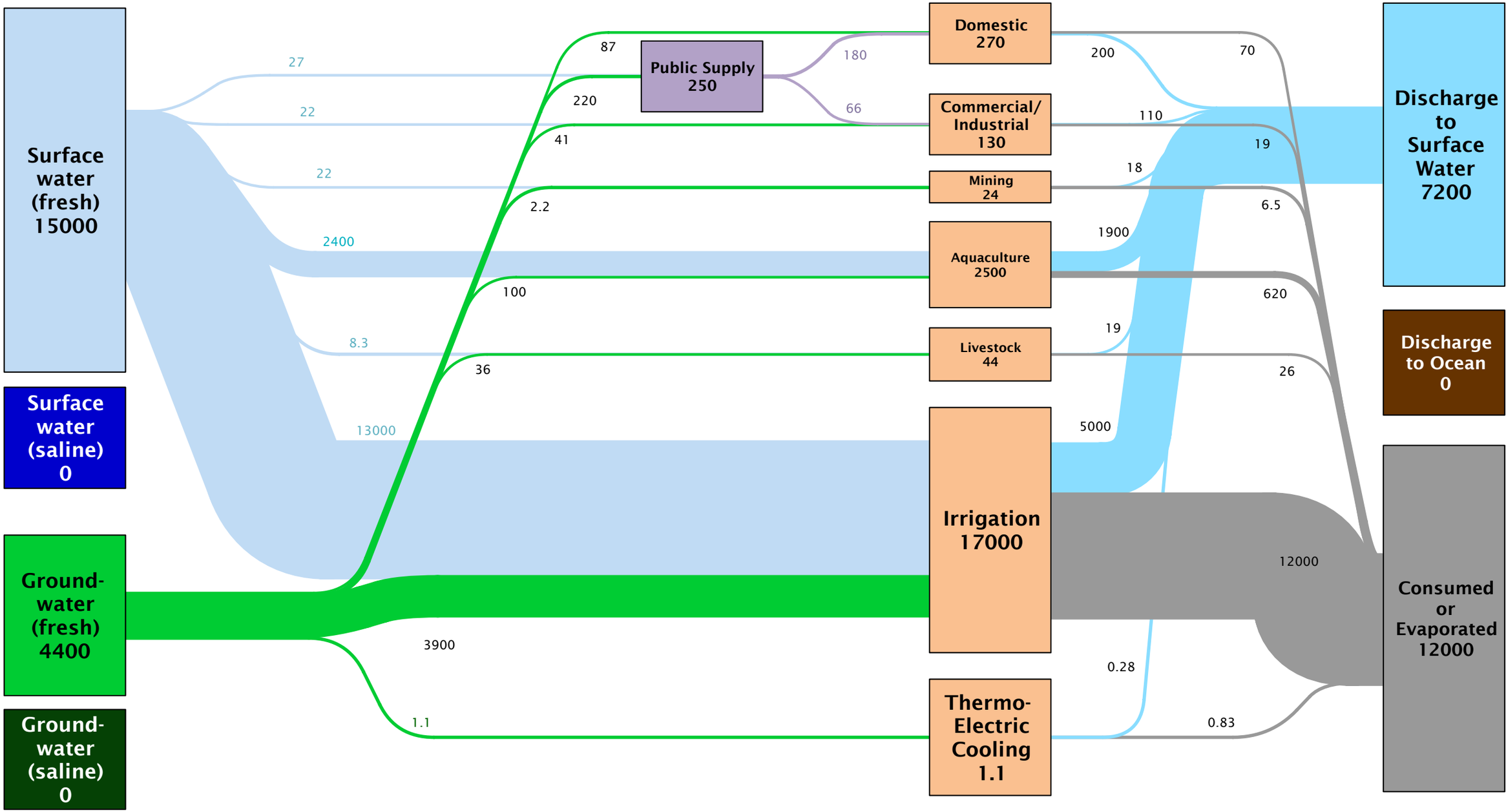
Estimated Idaho Water Flow in 2005: 20000 Million Gallons/Day



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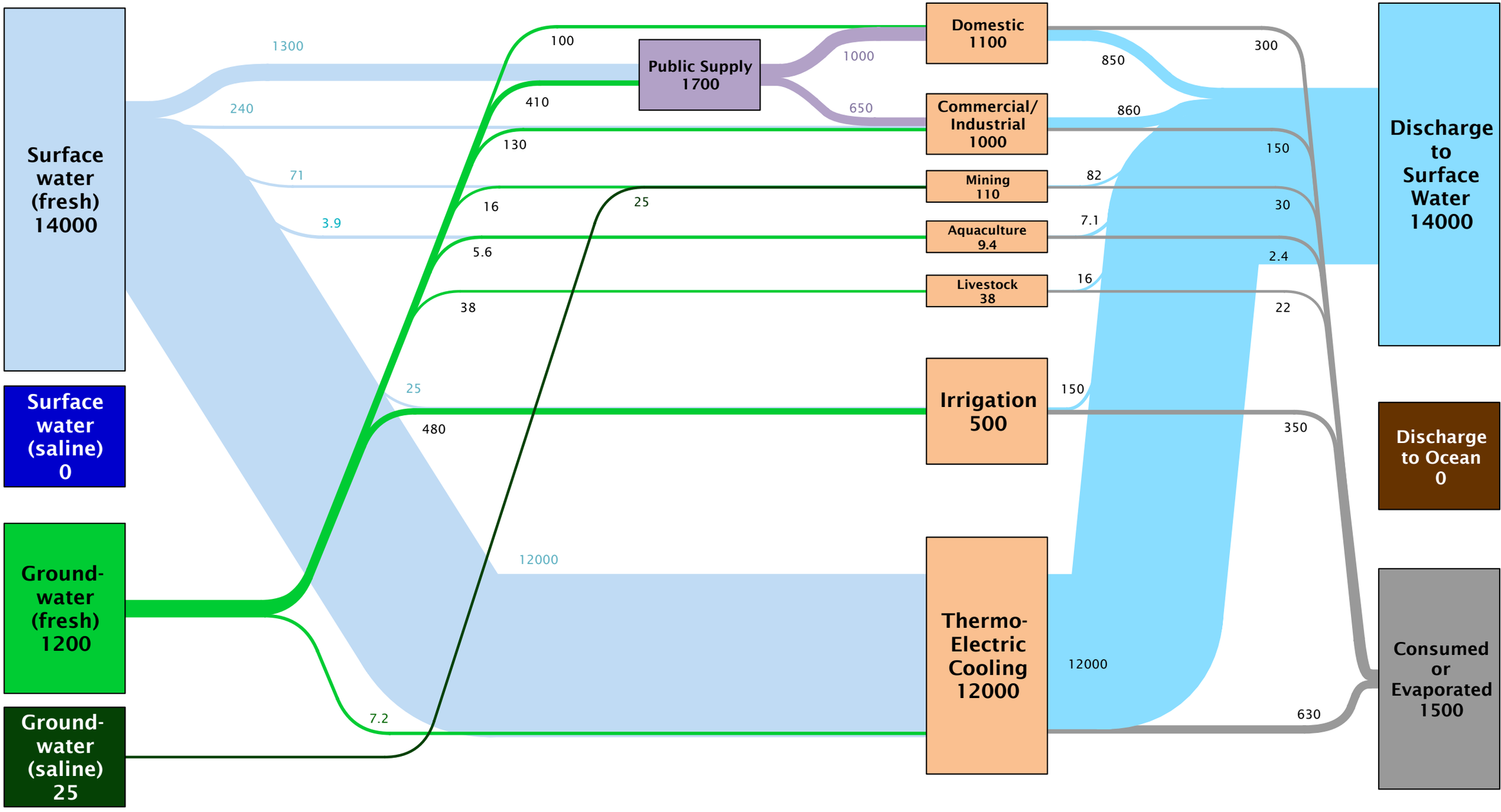
Estimated Illinois Water Flow in 2005: 15000 Million Gallons/Day



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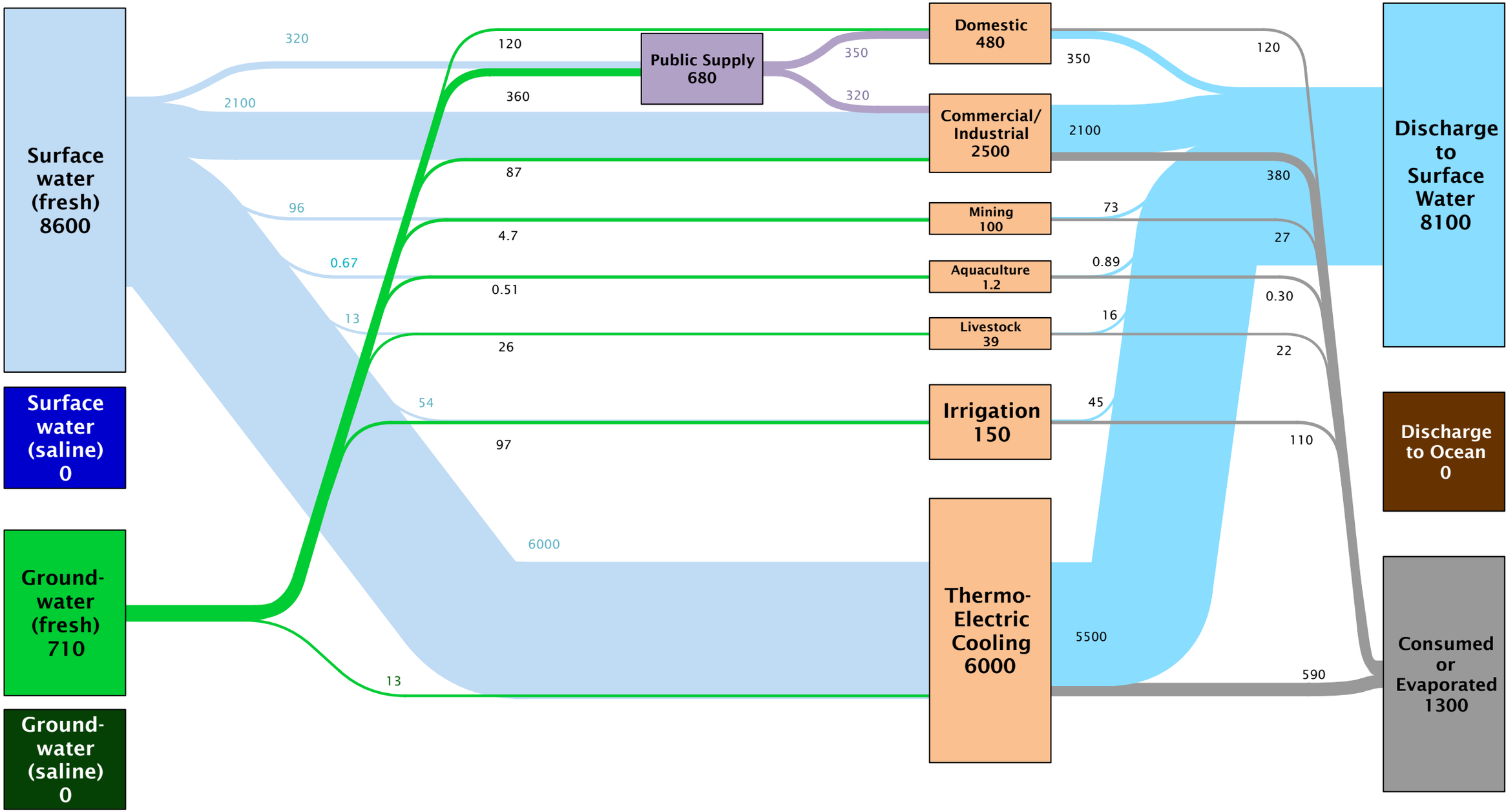
Estimated Indiana Water Flow in 2005: 9300 Million Gallons/Day



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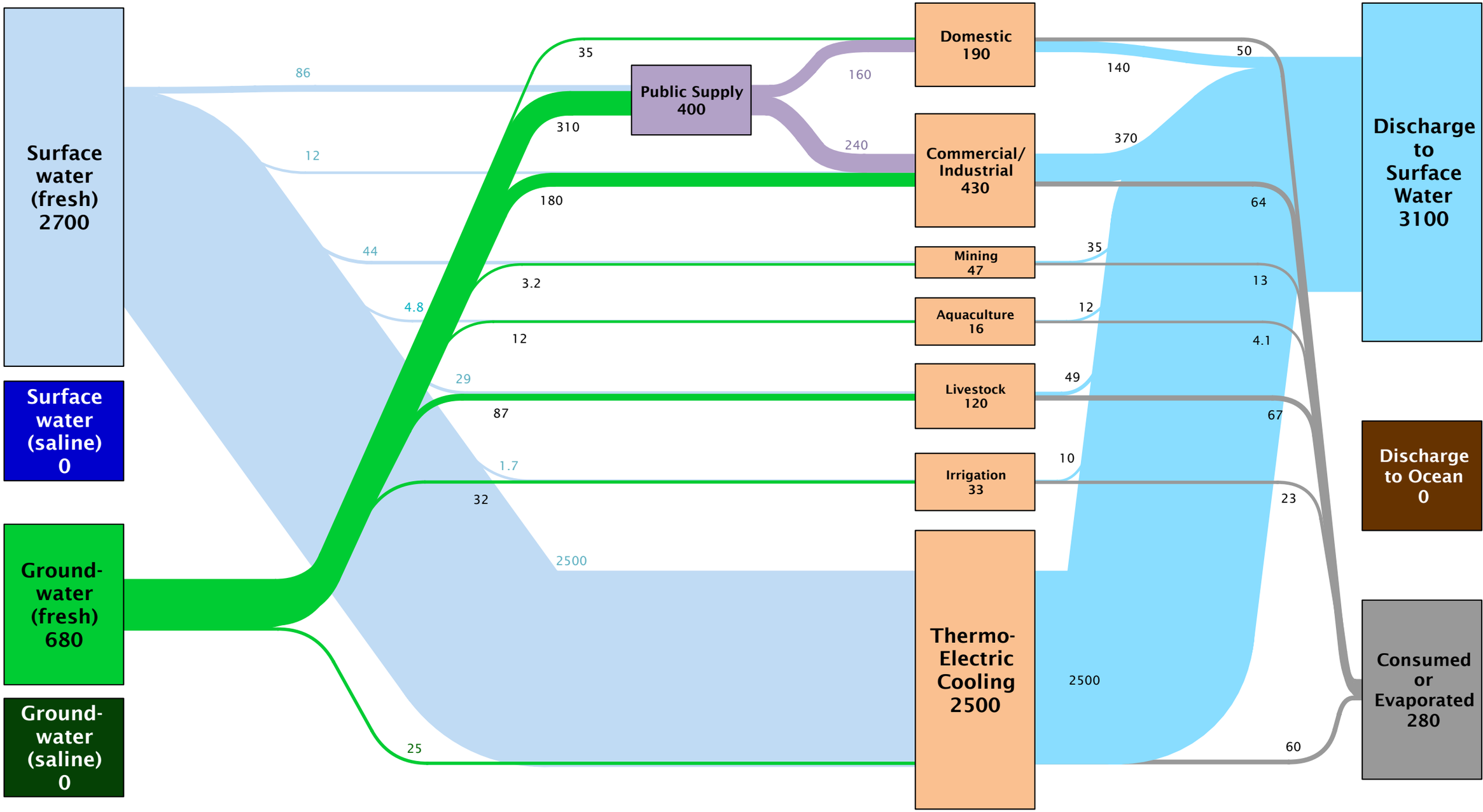
Estimated Iowa Water Flow in 2005: 3400 Million Gallons/Day



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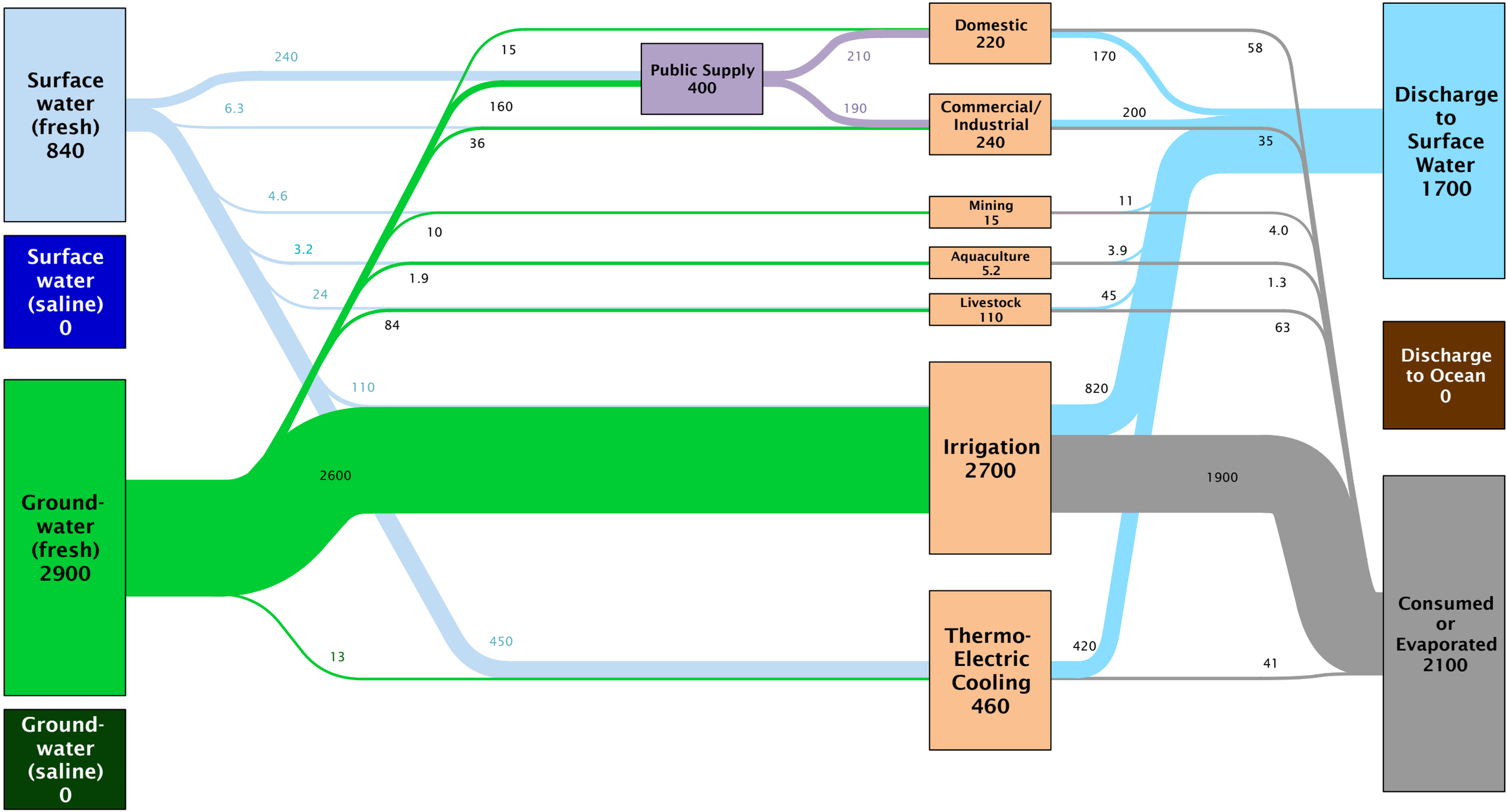
Estimated Kansas Water Flow in 2005: 3800 Million Gallons/Day



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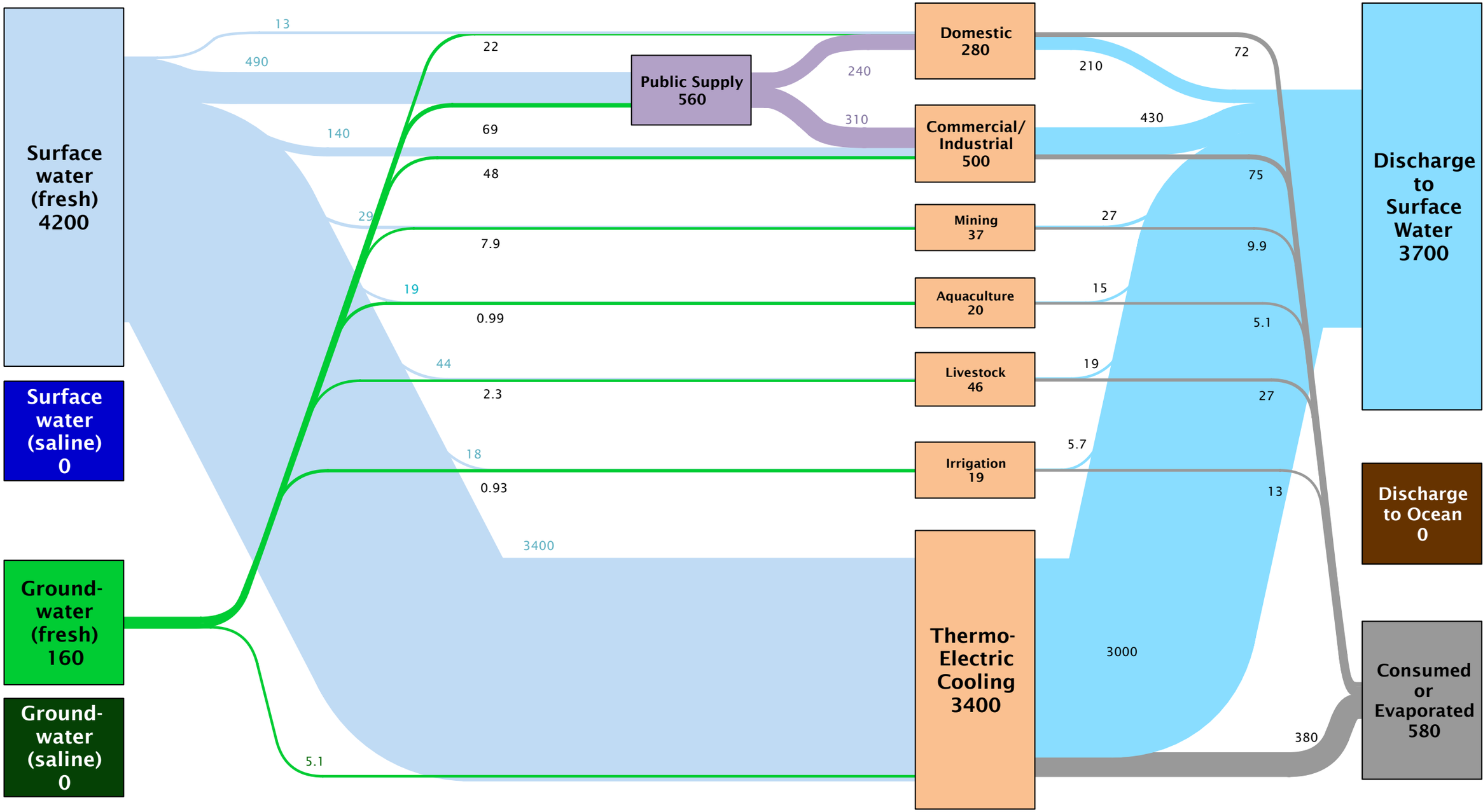
Estimated Kentucky Water Flow in 2005: 4300 Million Gallons/Day



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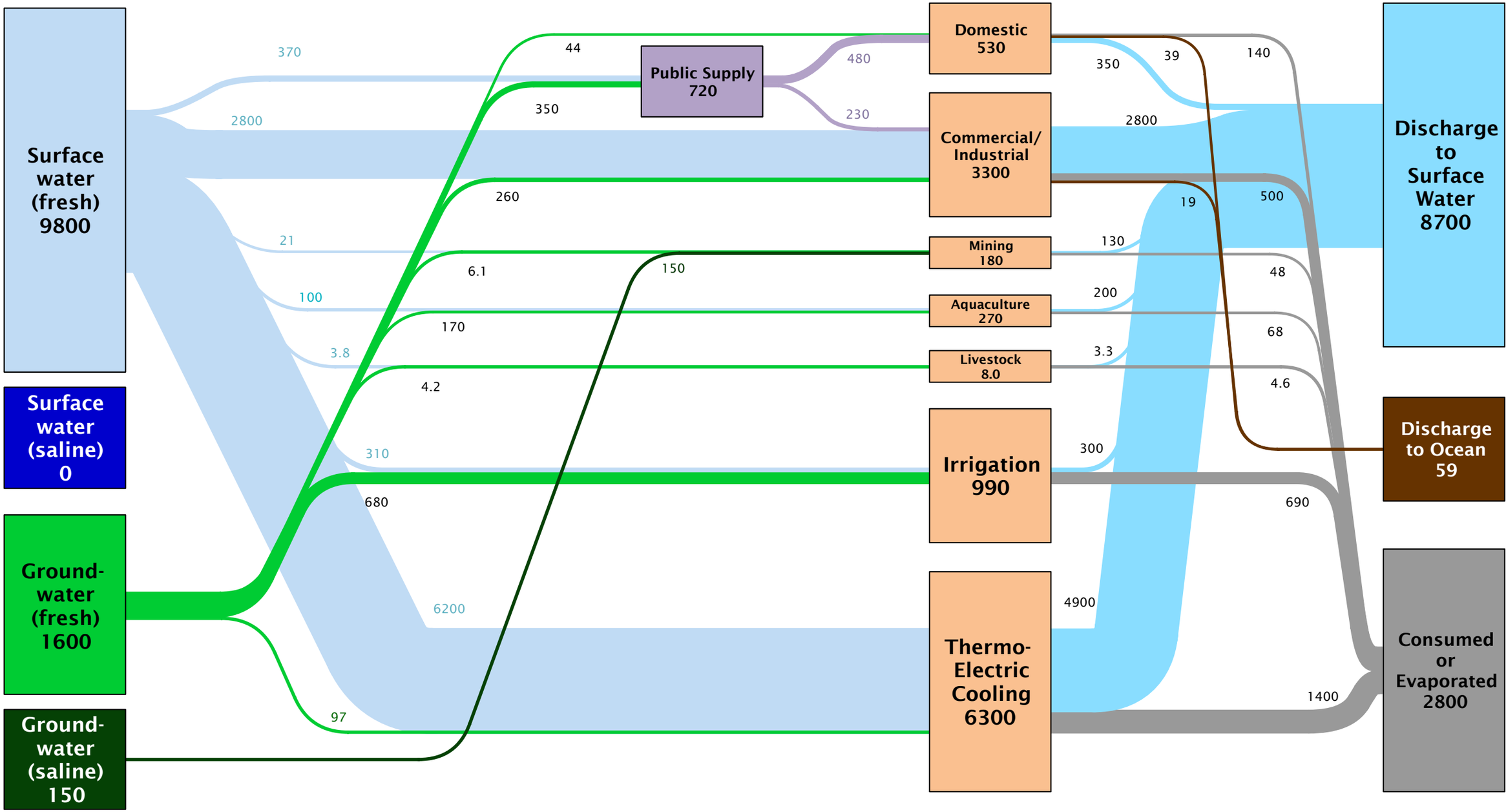
Estimated Louisiana Water Flow in 2005: 12000 Million Gallons/Day



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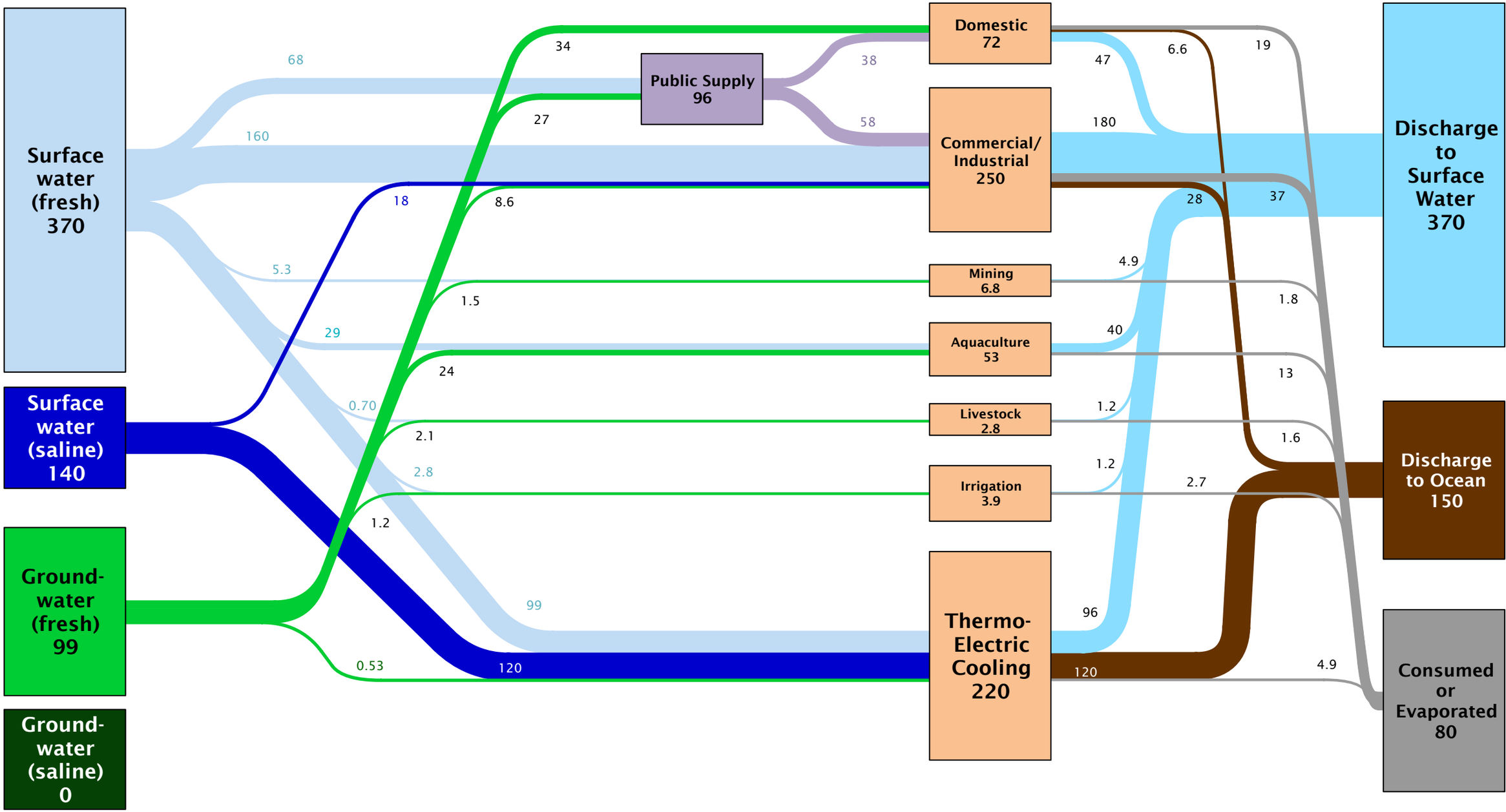
Estimated Maine Water Flow in 2005: 600 Million Gallons/Day



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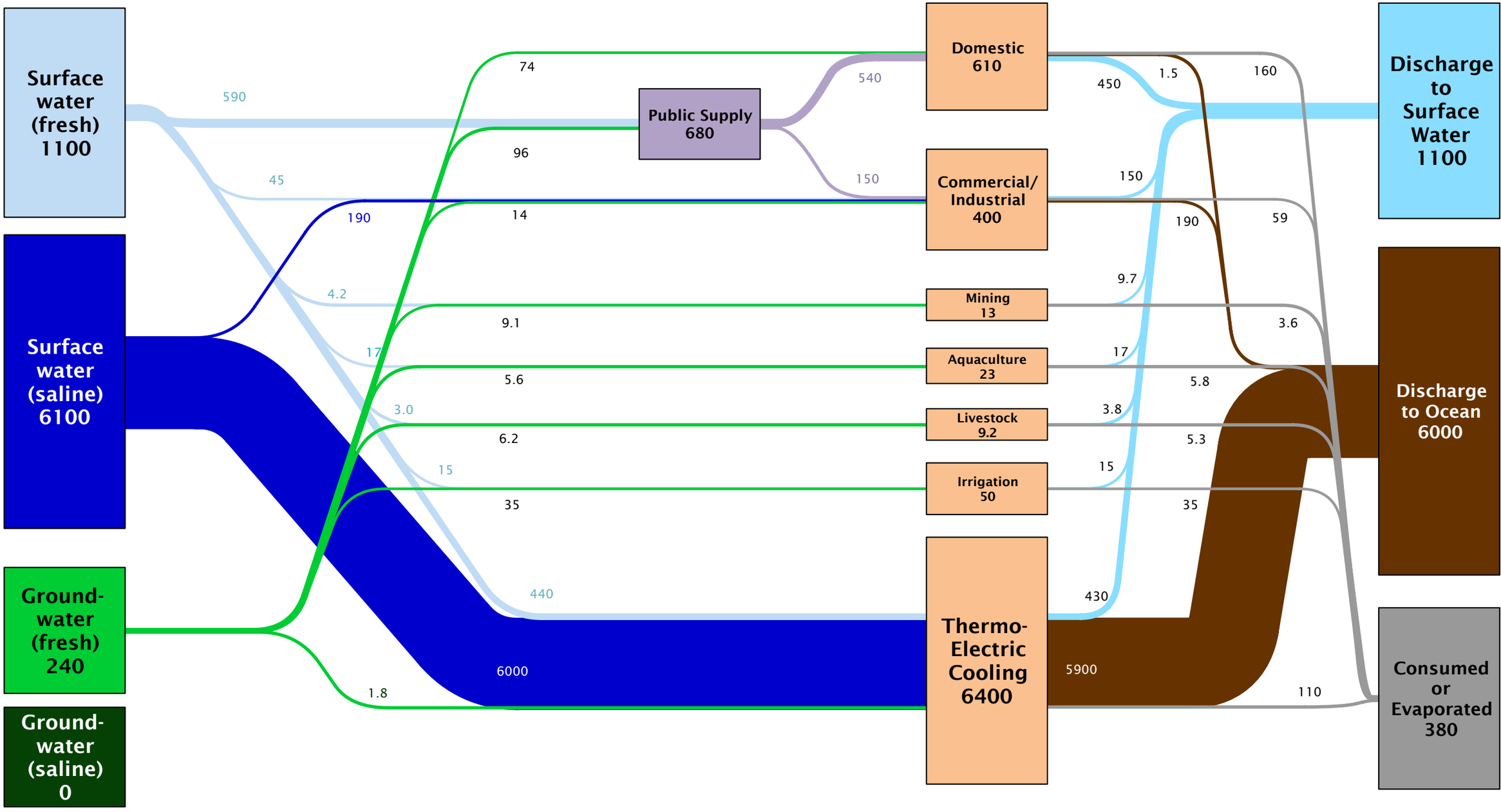
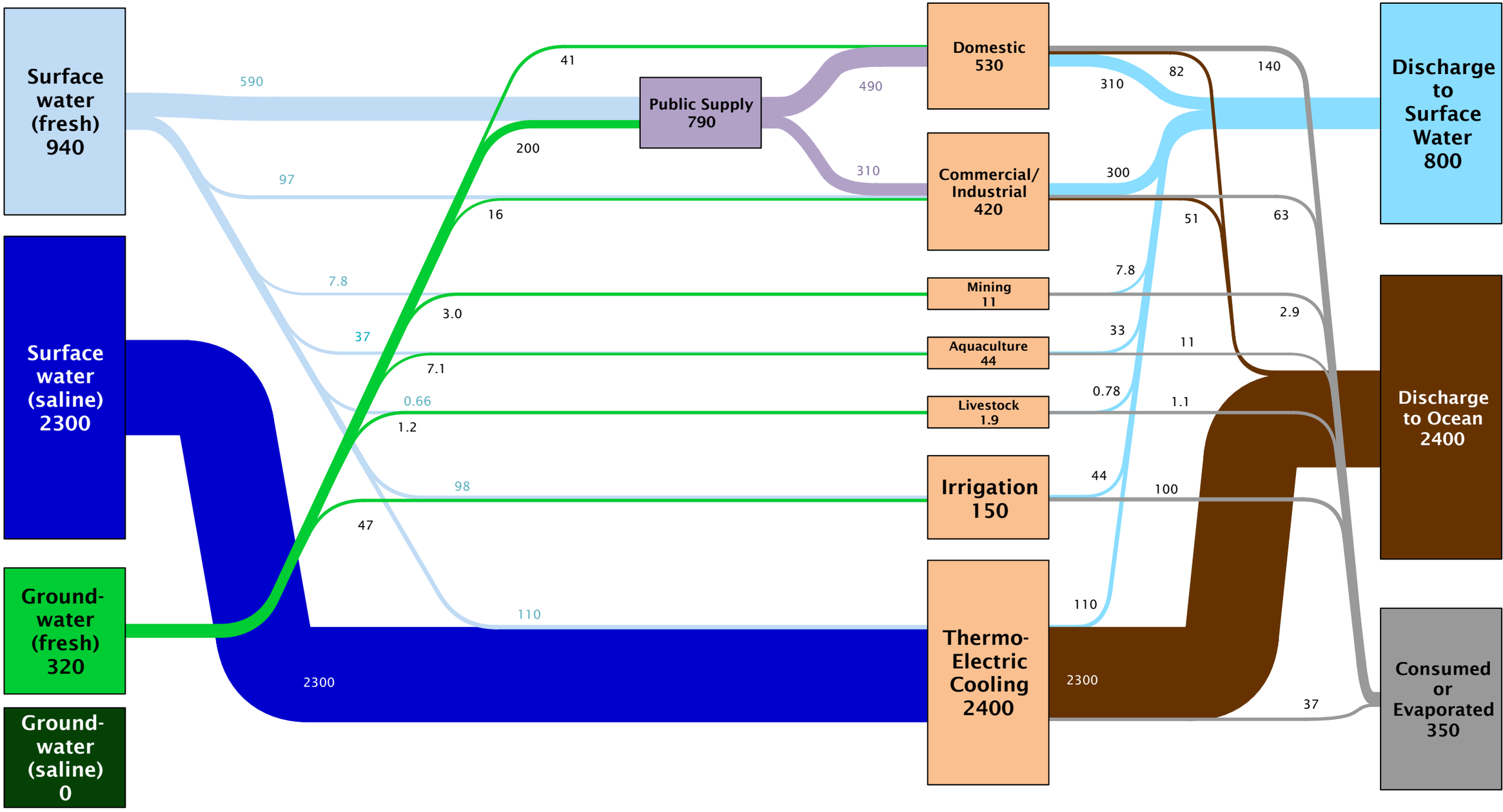
Estimated Maryland Water Flow in 2005: 7500 Million Gallons/Day



Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Massachusetts Water Flow in 2005: 3600 Million Gallons/Day



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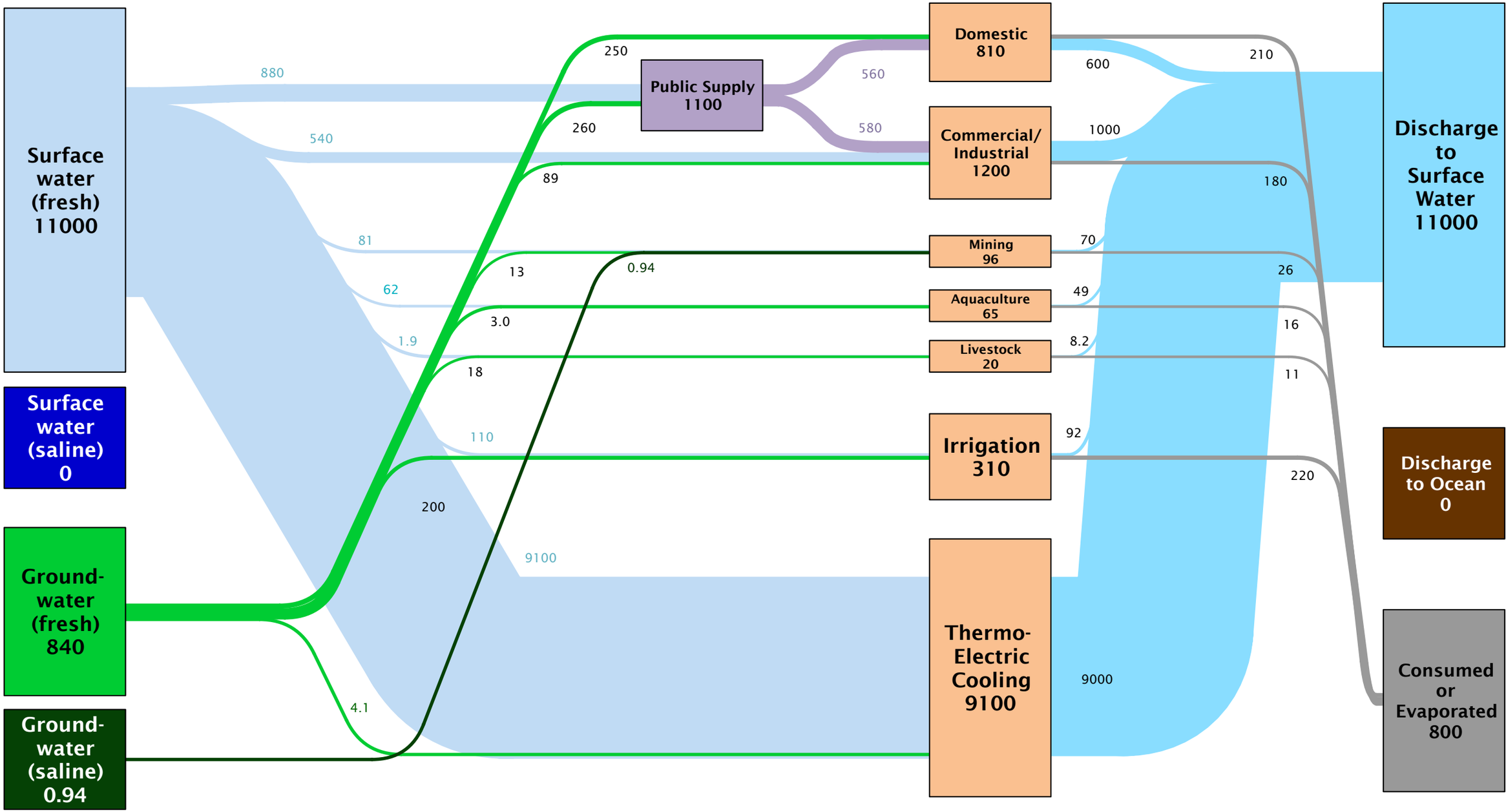
Estimated Michigan Water Flow in 2005: 12000 Million Gallons/Day



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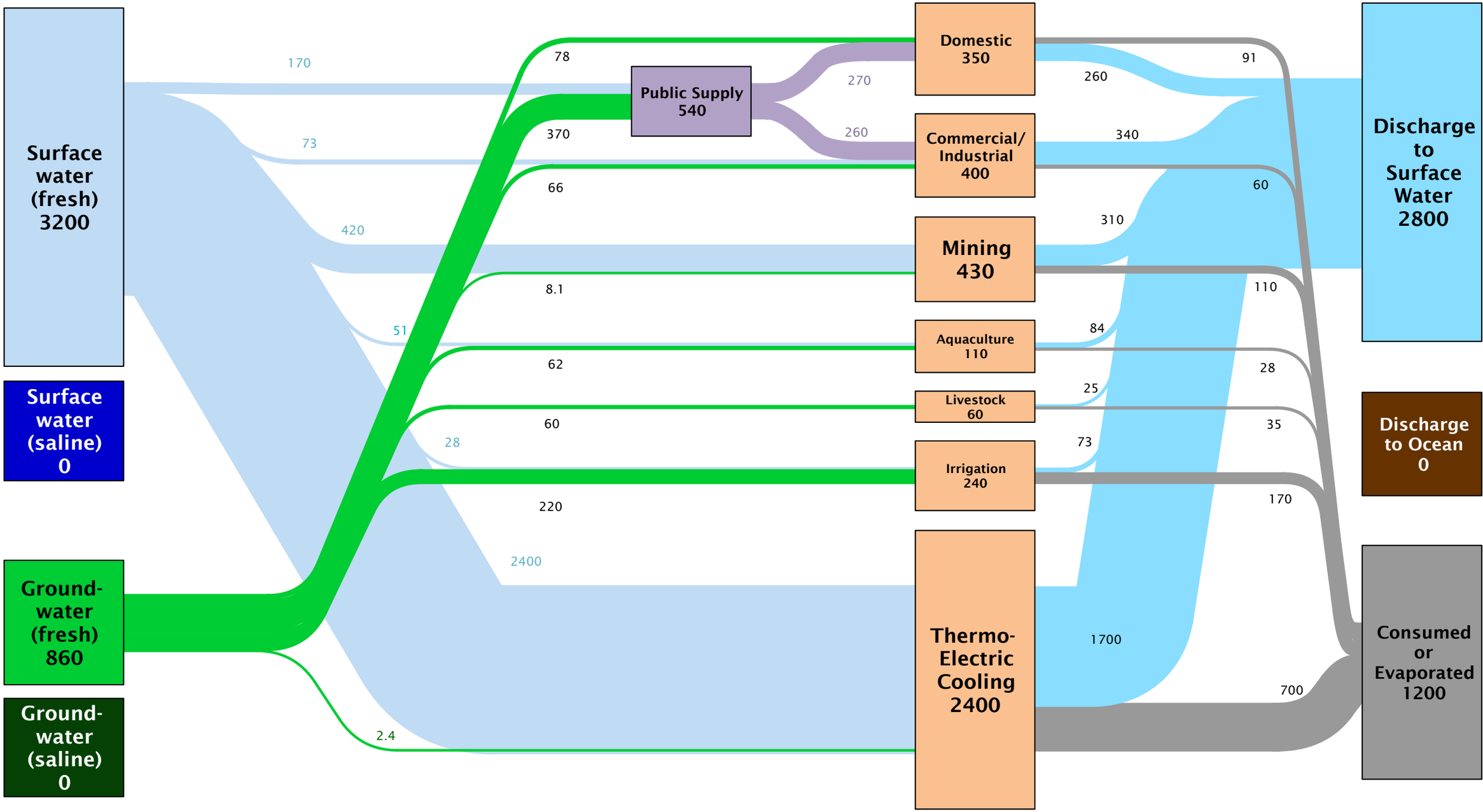
Estimated Minnesota Water Flow in 2005: 4000 Million Gallons/Day



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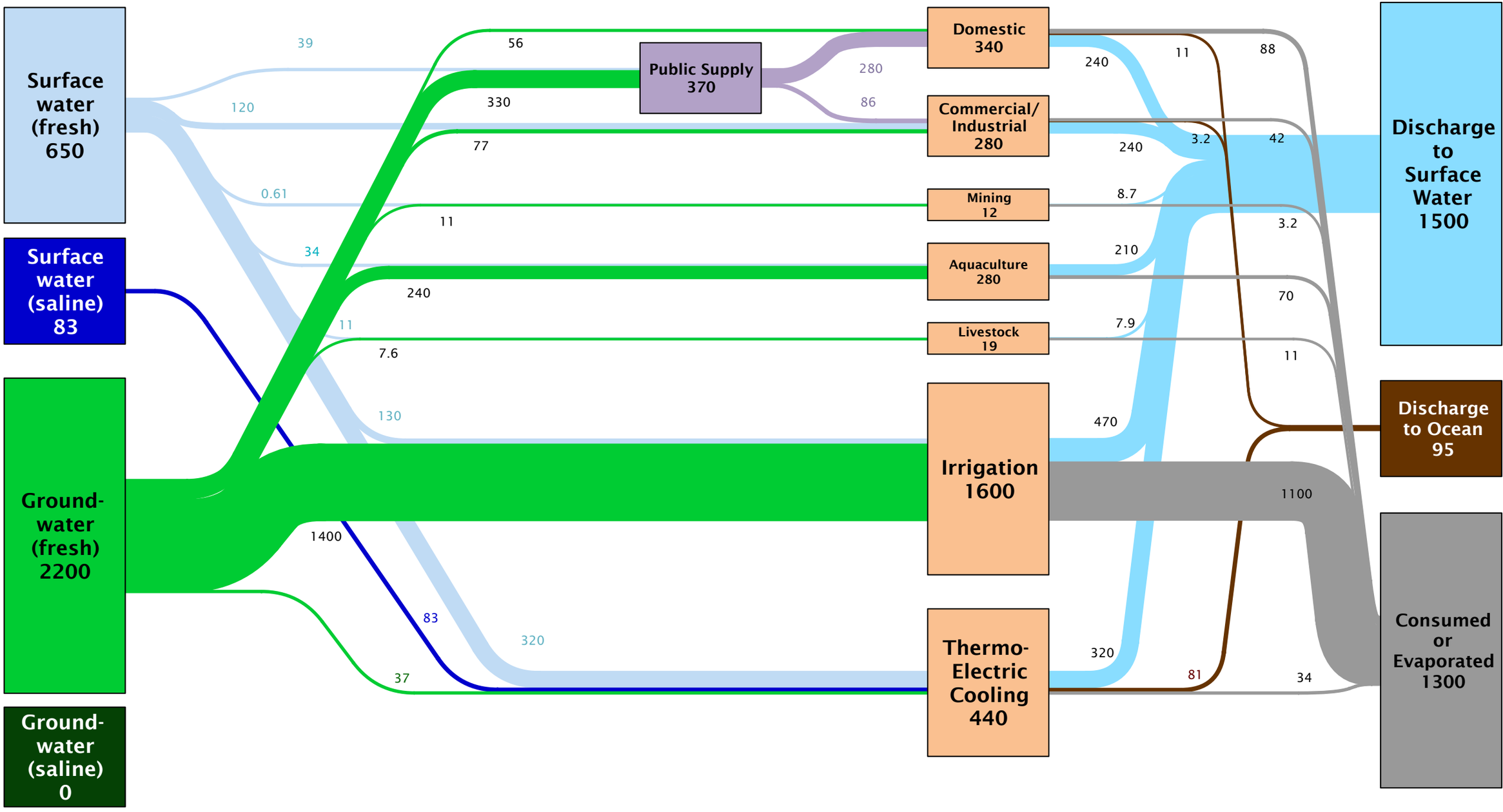
Estimated Mississippi Water Flow in 2005: 2900 Million Gallons/Day



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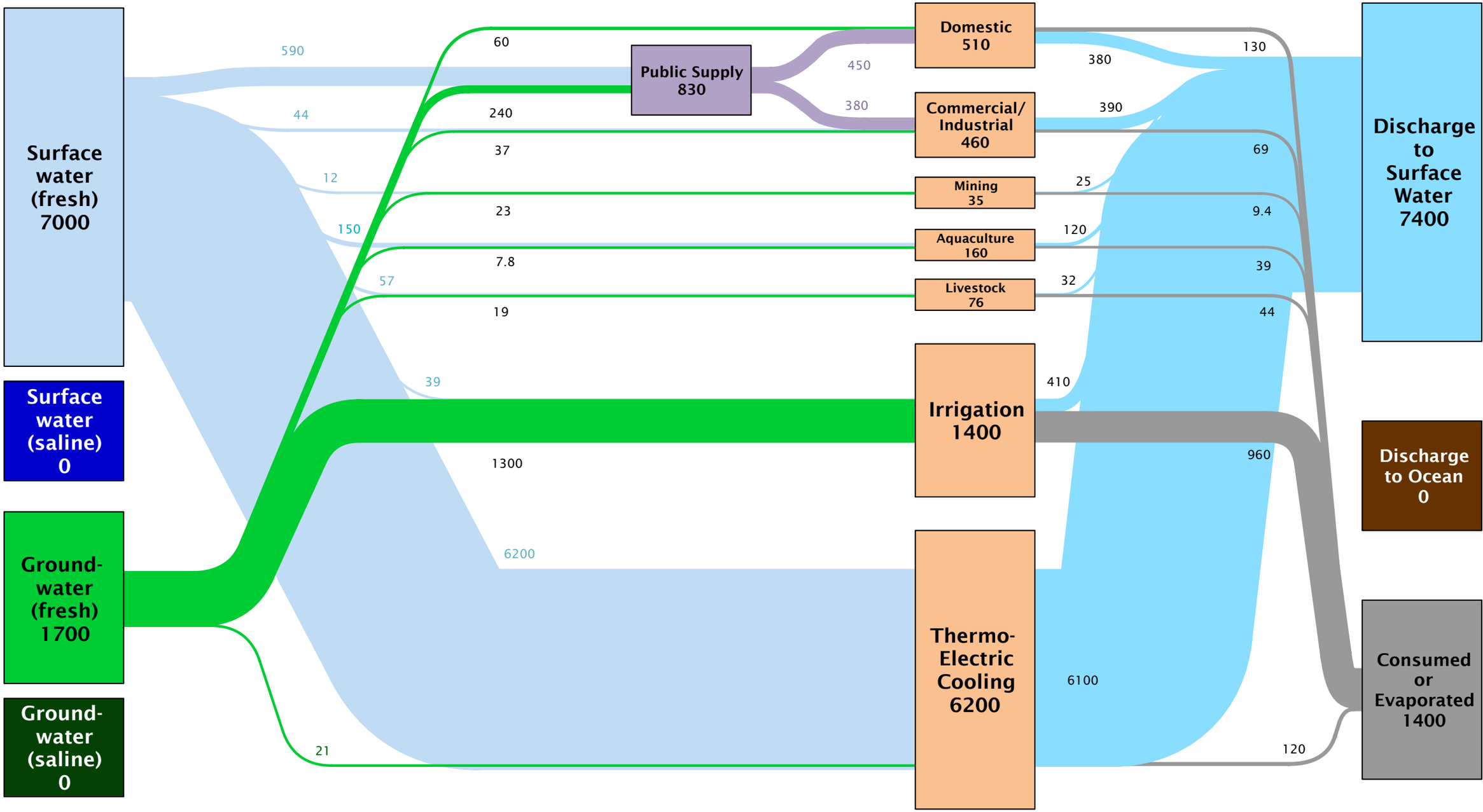
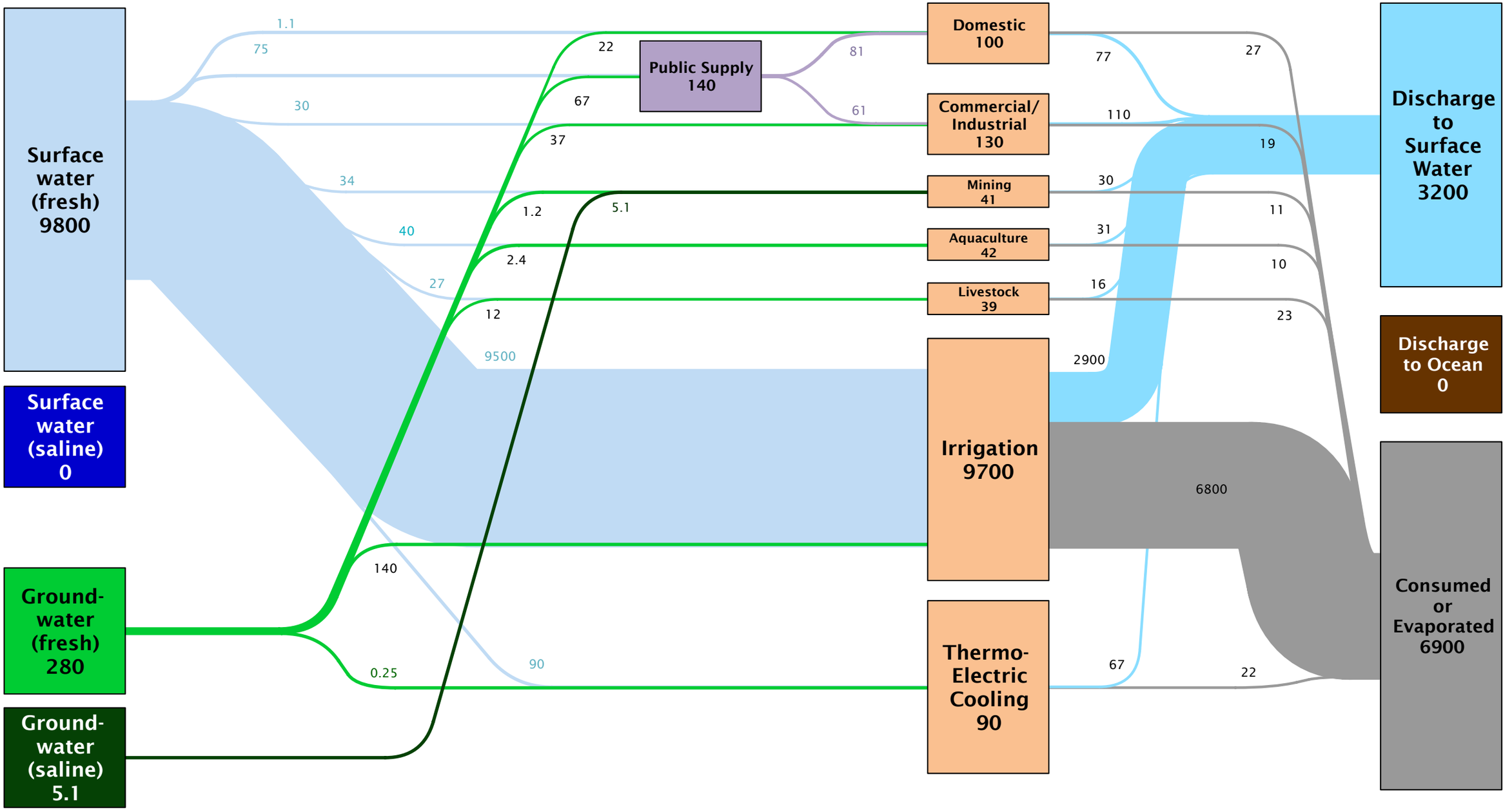
Estimated Missouri Water Flow in 2005: 8800 Million Gallons/Day



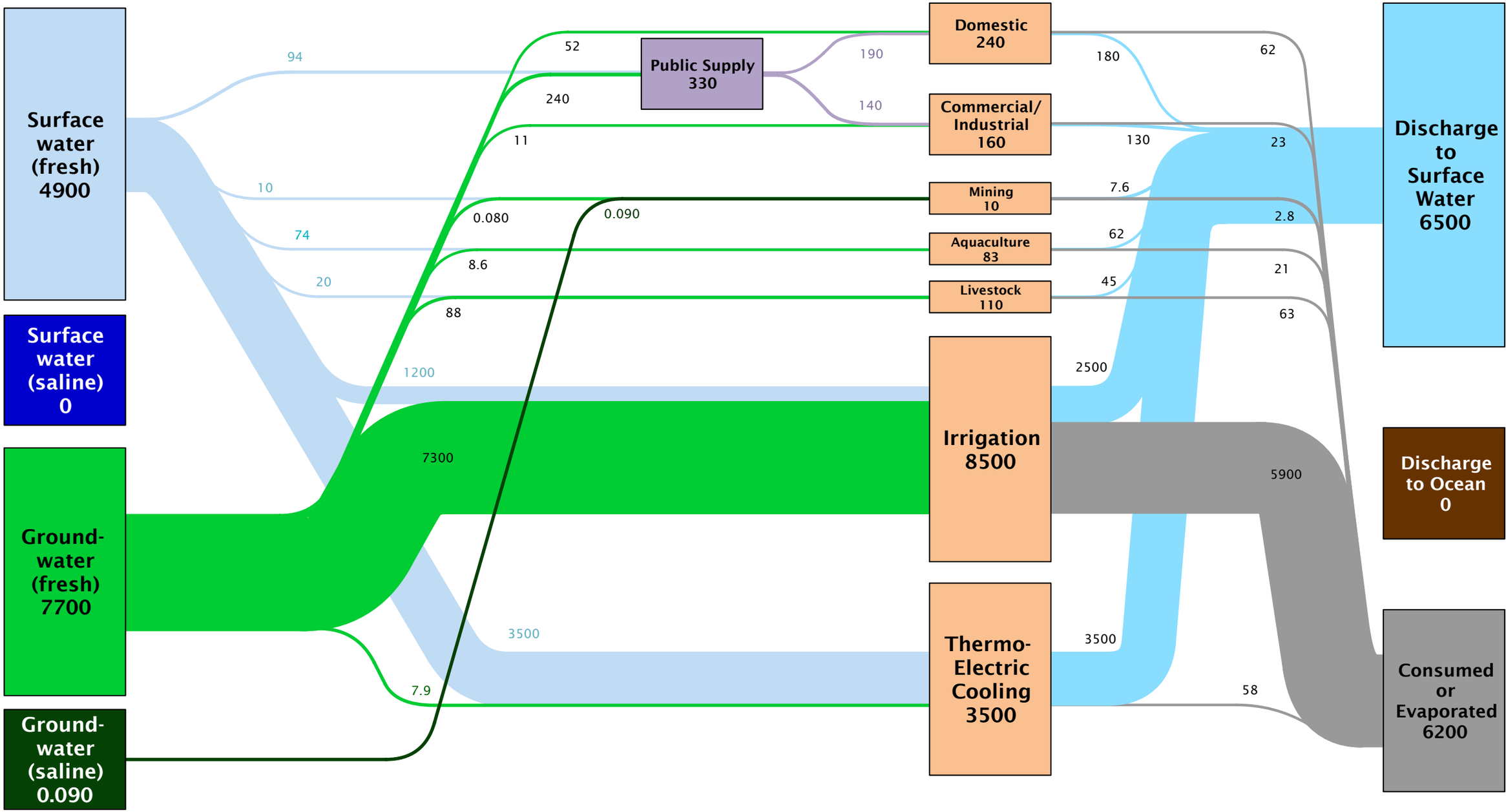
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Montana Water Flow in 2005: 10000 Million Gallons/Day



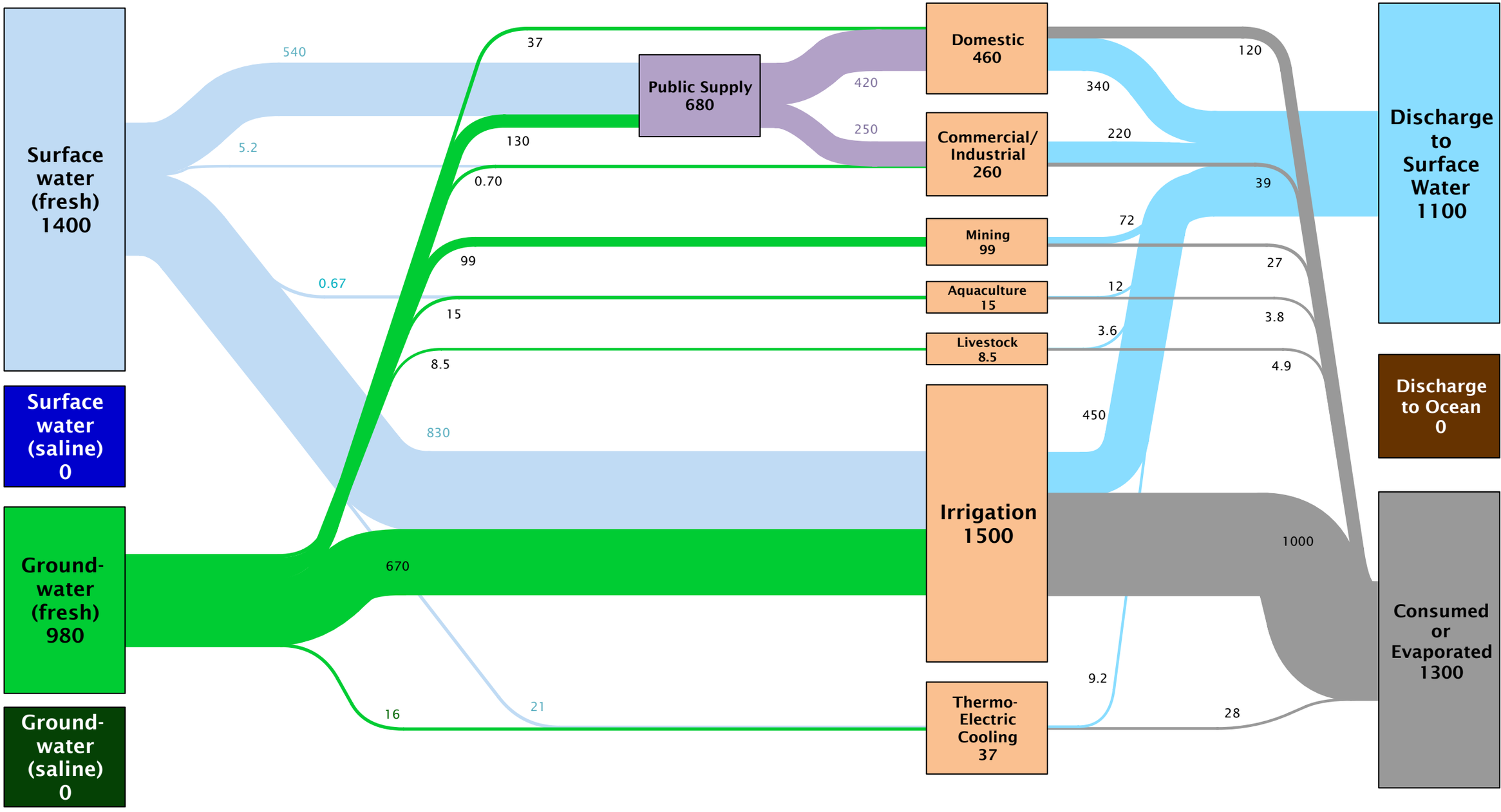
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Nebraska Water Flow in 2005: 13000 Million Gallons/Day



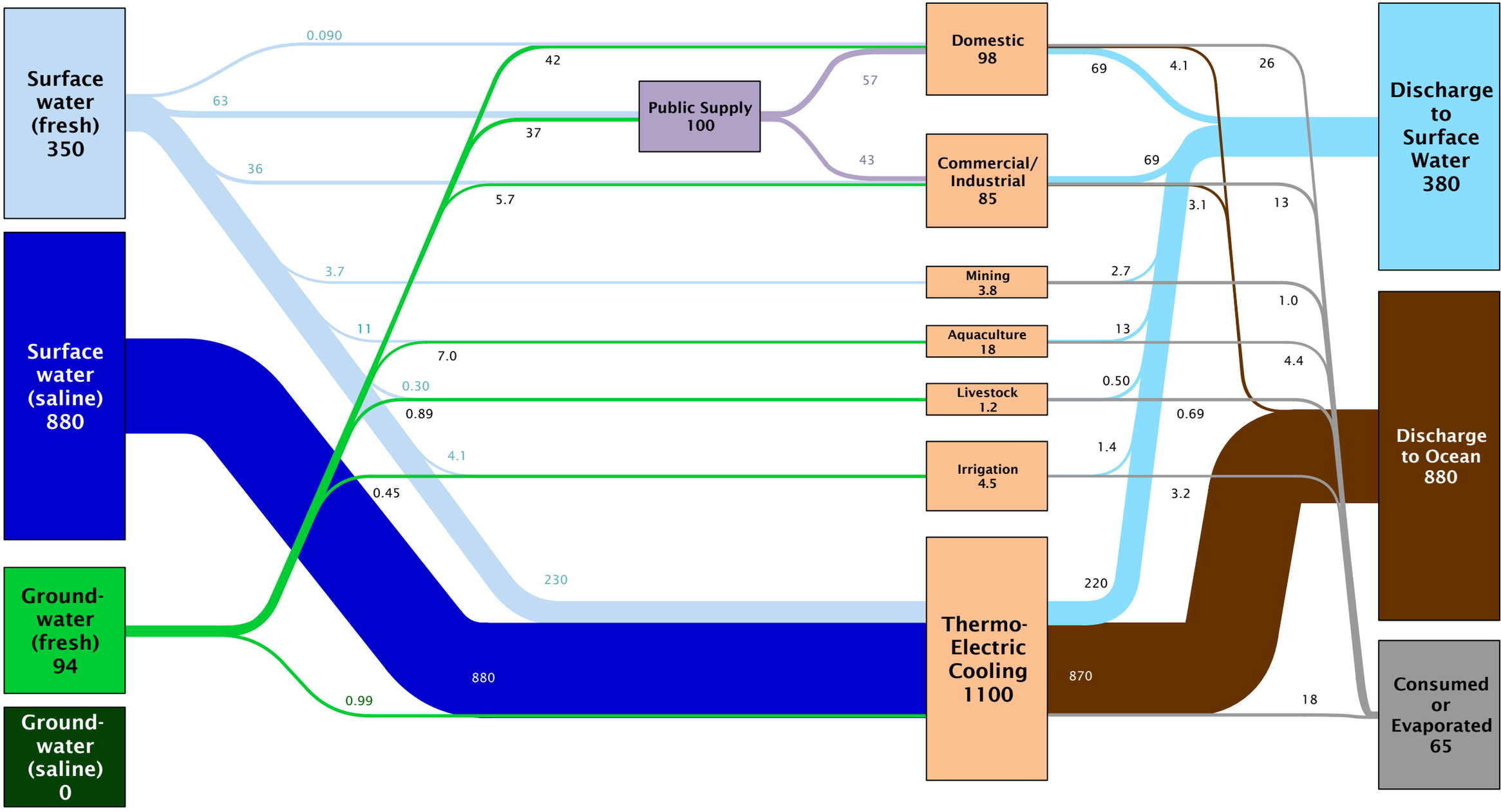
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Nevada Water Flow in 2005: 2400 Million Gallons/Day



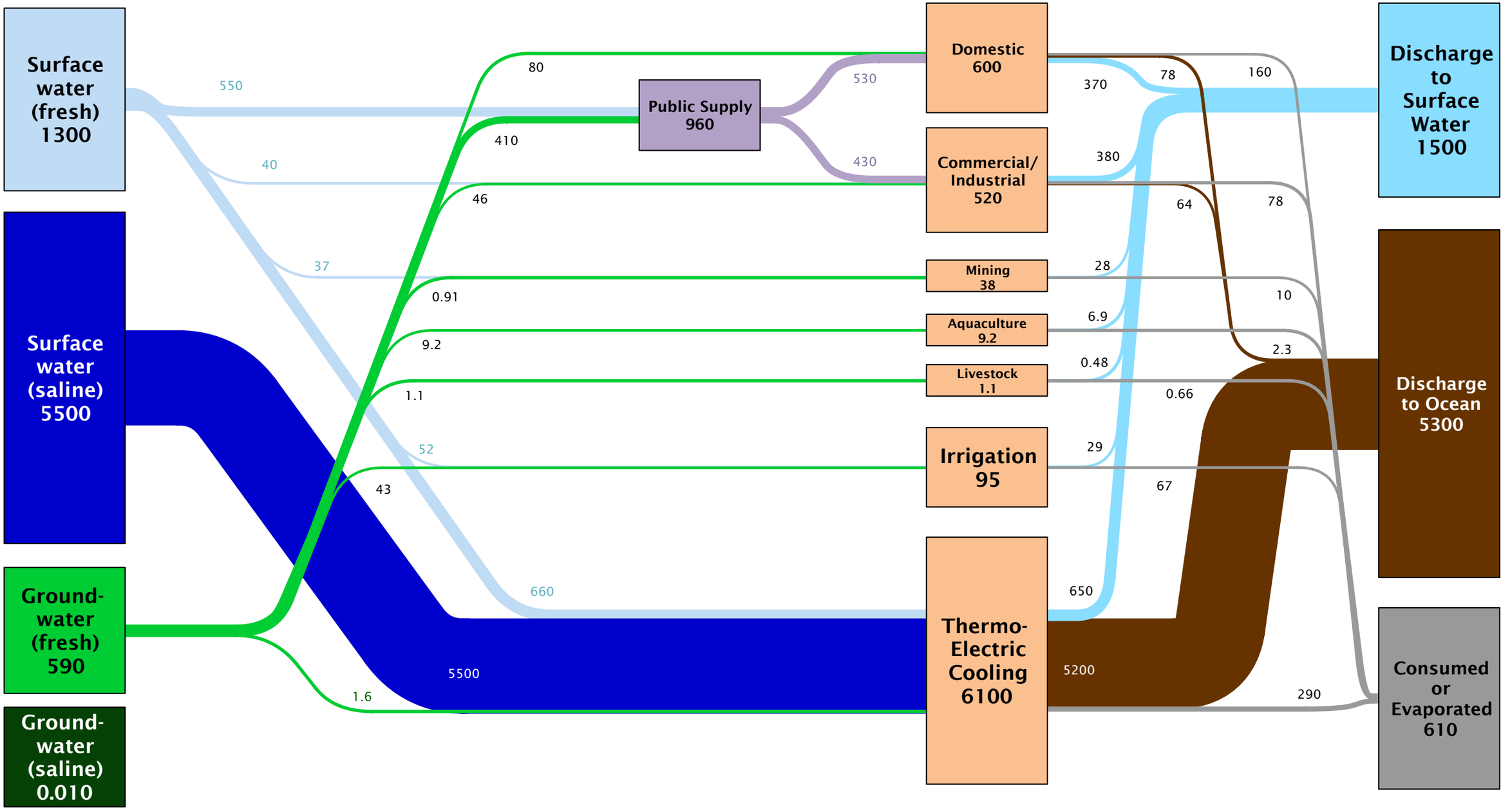
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated New Hampshire Water Flow in 2005: 1300 Million Gallons/Day



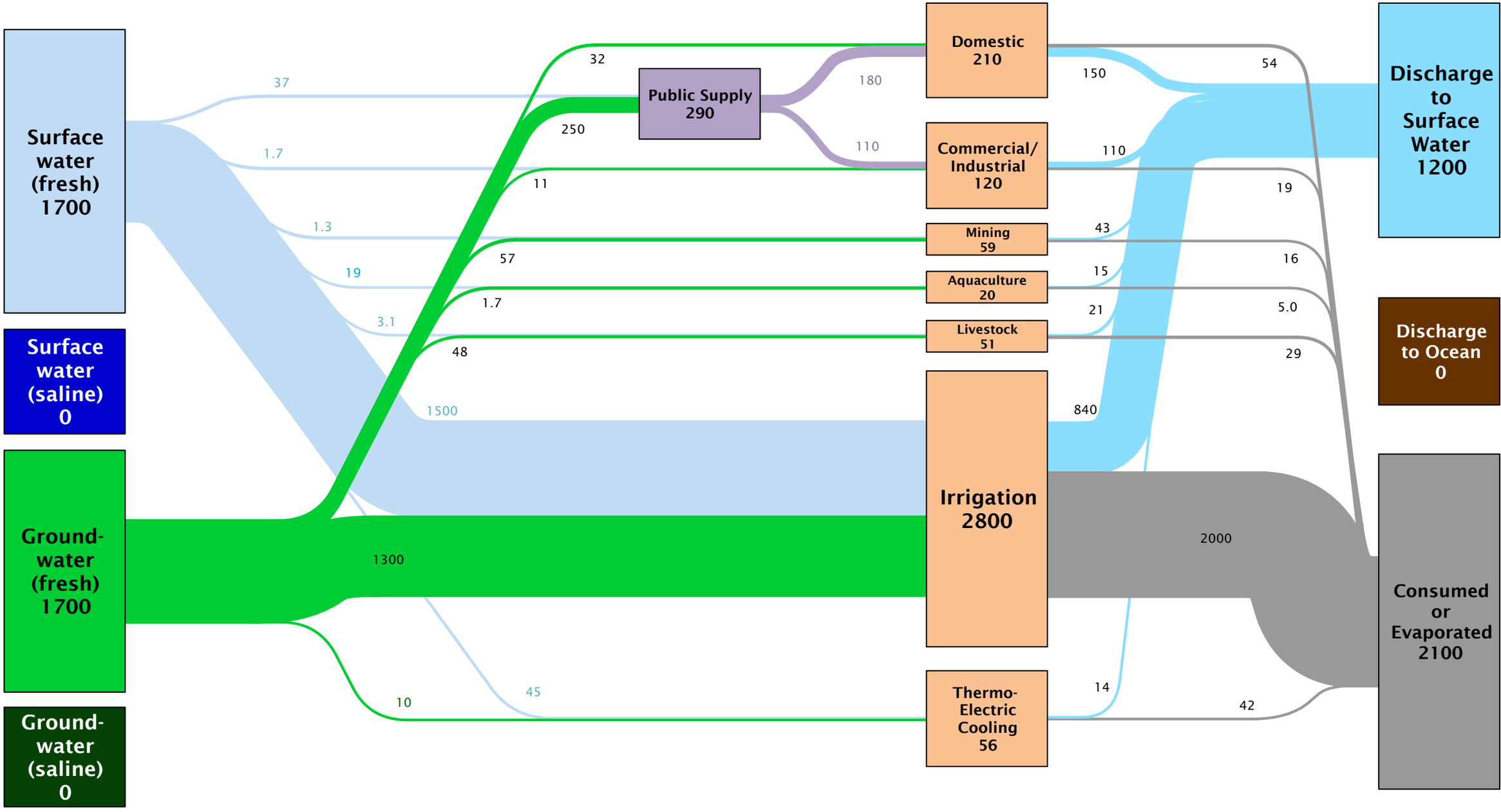
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated New Jersey Water Flow in 2005: 7400 Million Gallons/Day



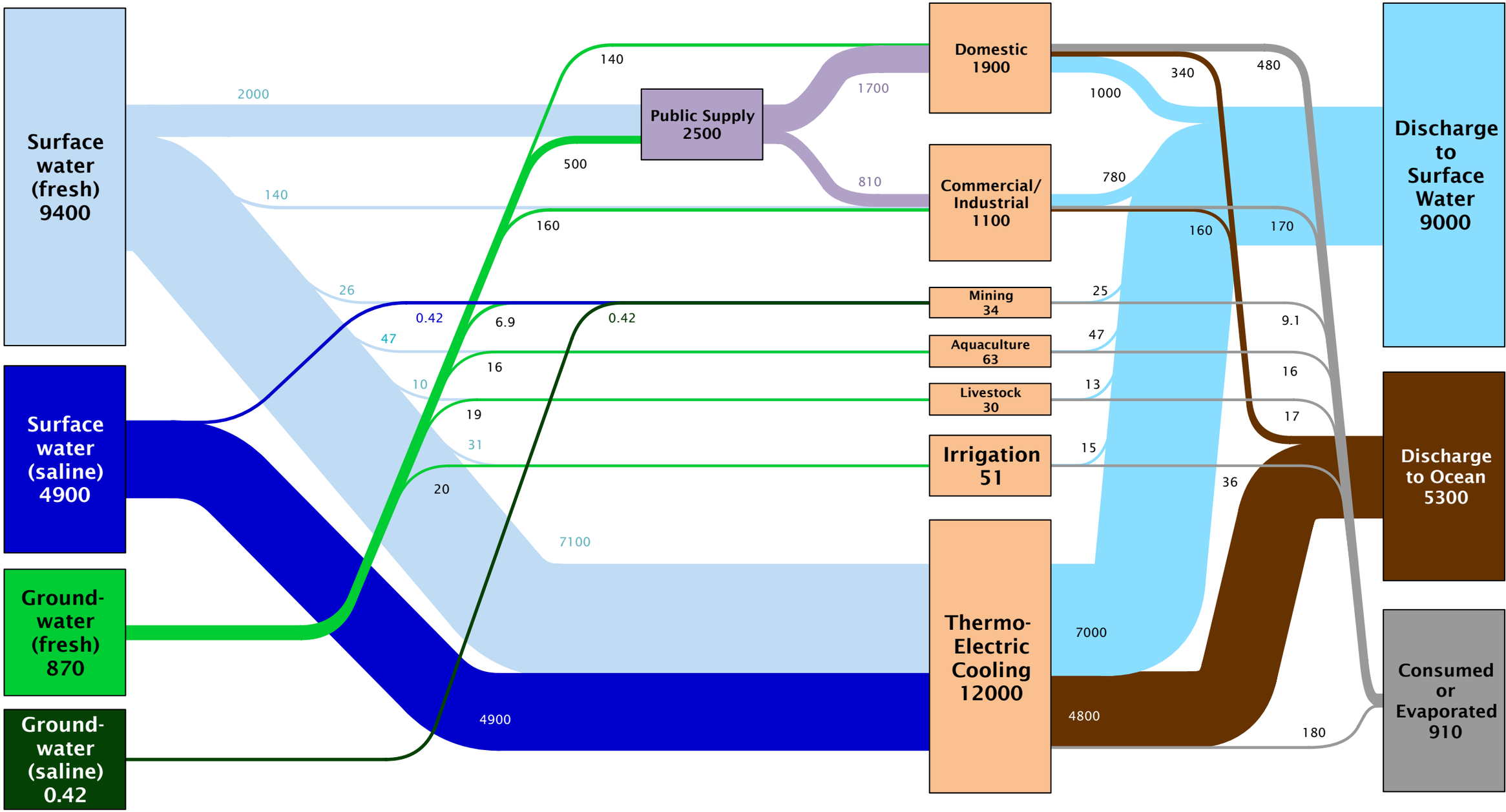
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated New Mexico Water Flow in 2005: 3300 Million Gallons/Day



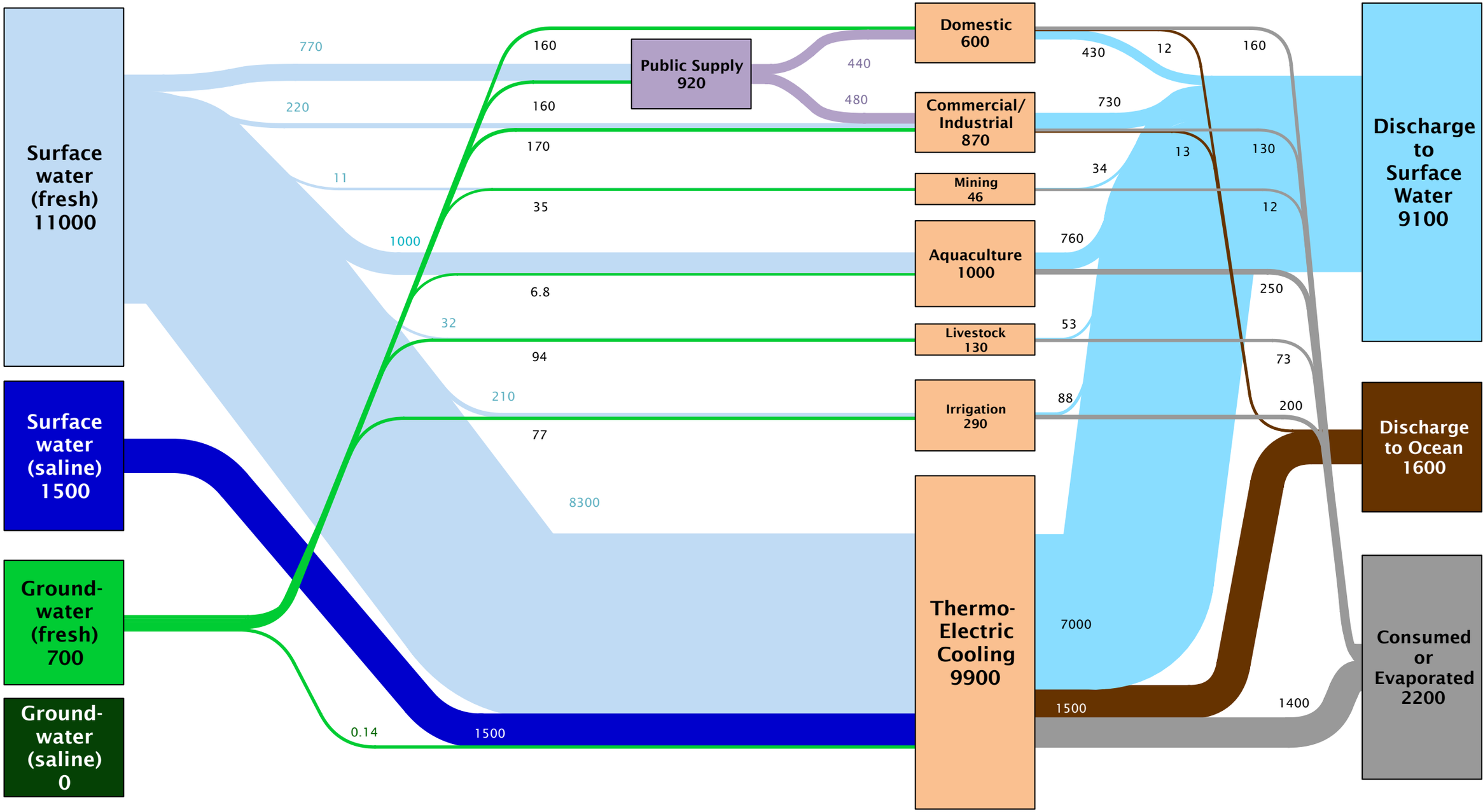
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated New York Water Flow in 2005: 15000 Million Gallons/Day



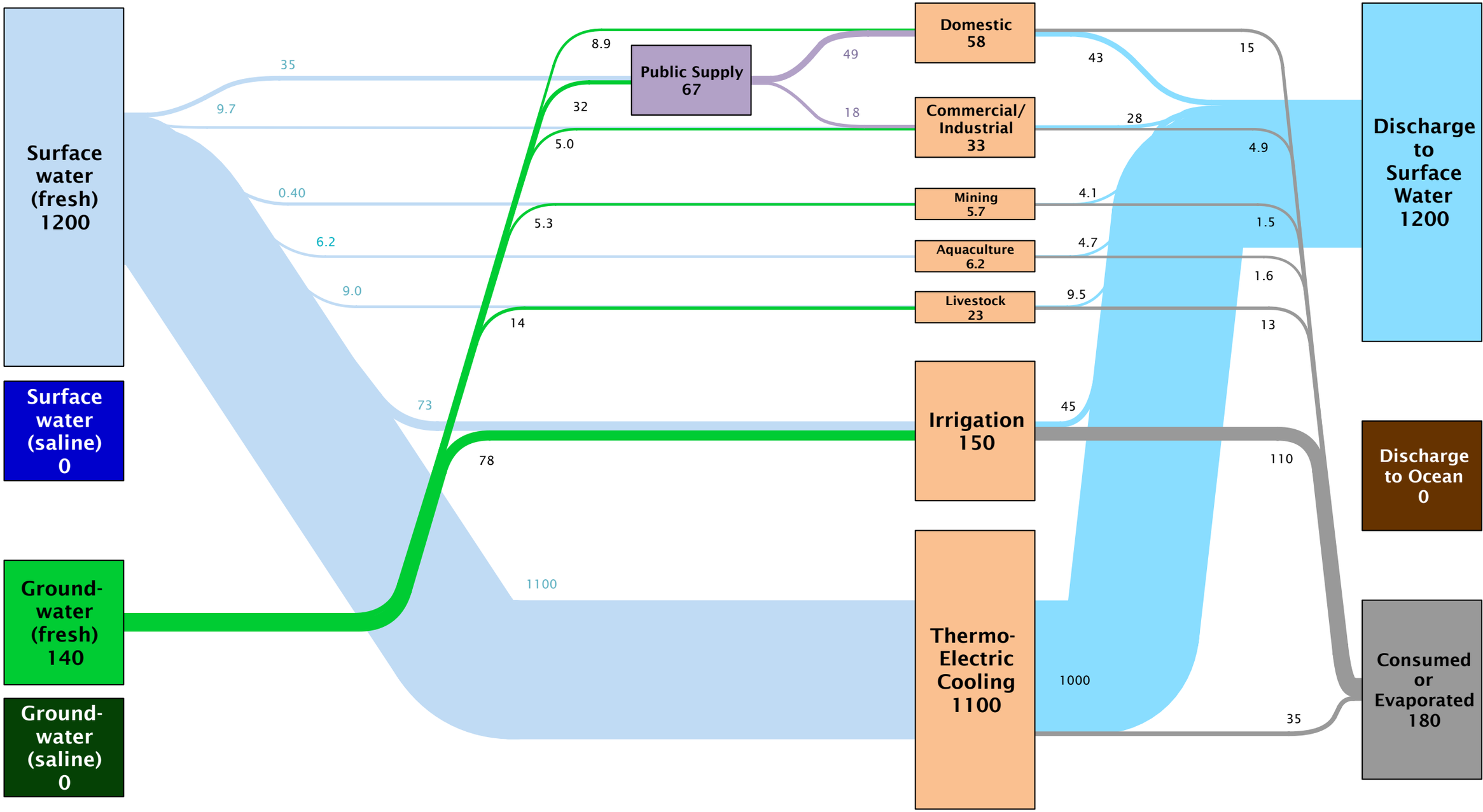
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated North Carolina Water Flow in 2005: 13000 Million Gallons/Day



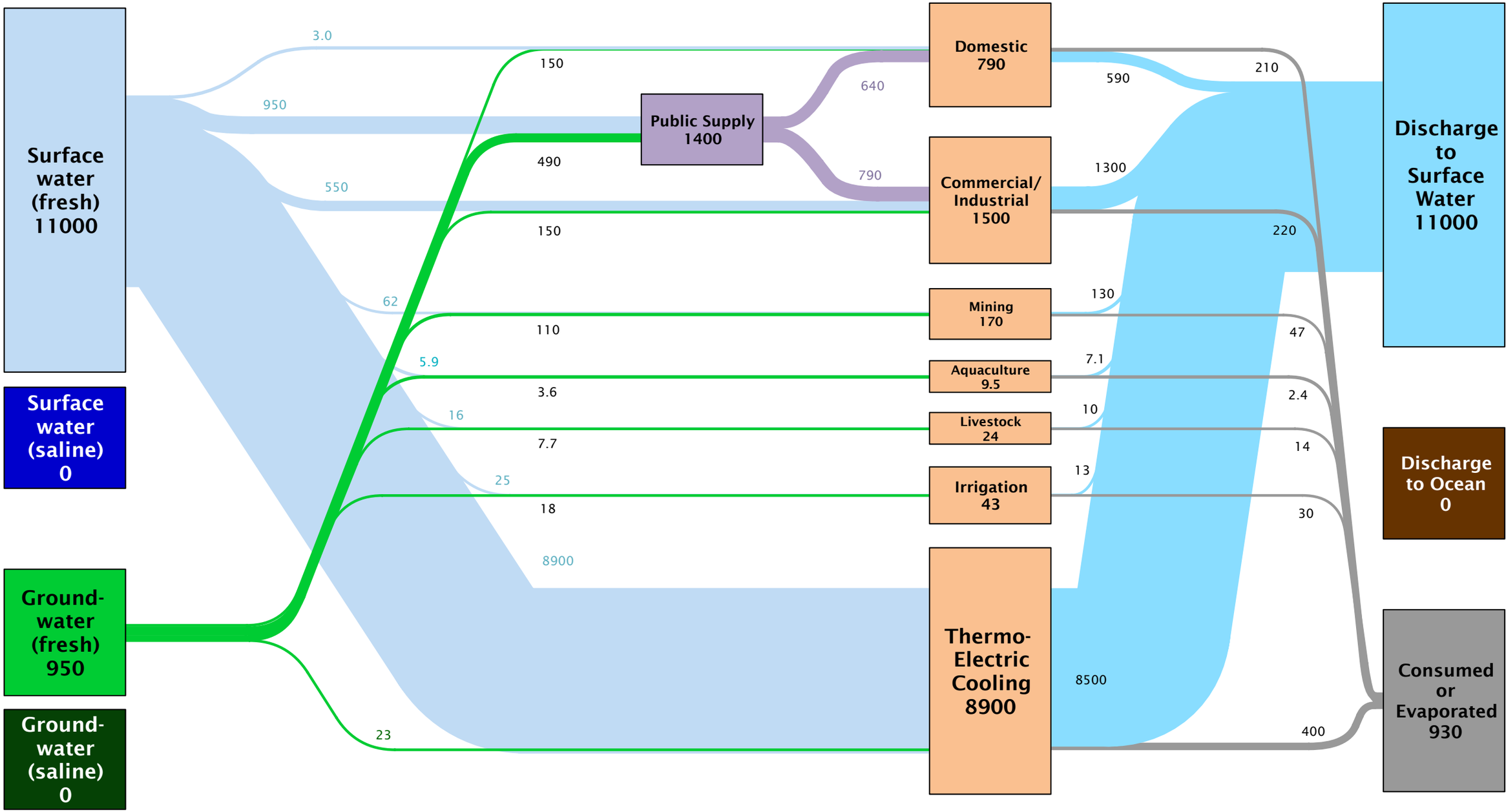
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated North Dakota Water Flow in 2005: 1300 Million Gallons/Day



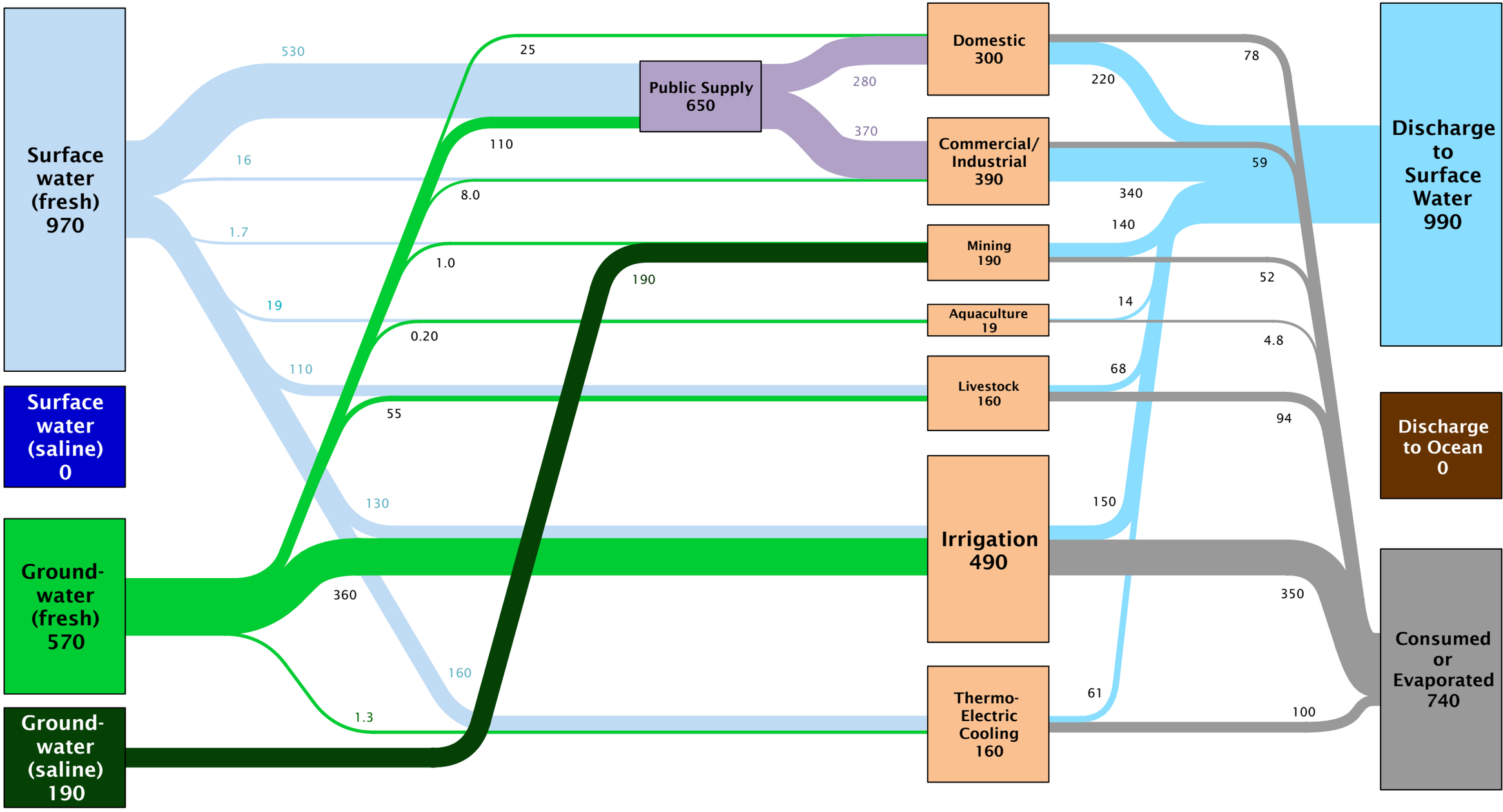
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Ohio Water Flow in 2005: 11000 Million Gallons/Day



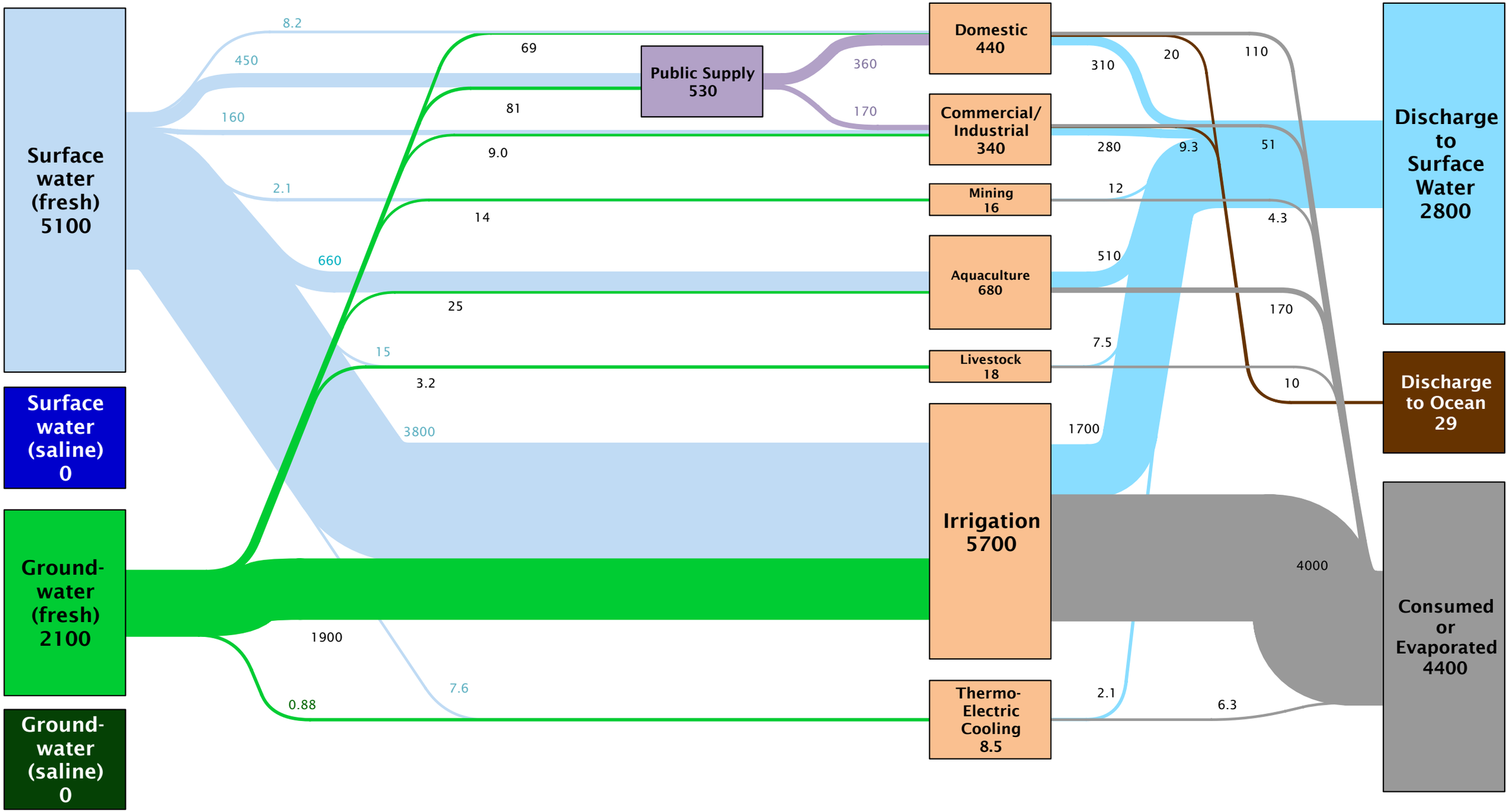
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Oklahoma Water Flow in 2005: 1700 Million Gallons/Day



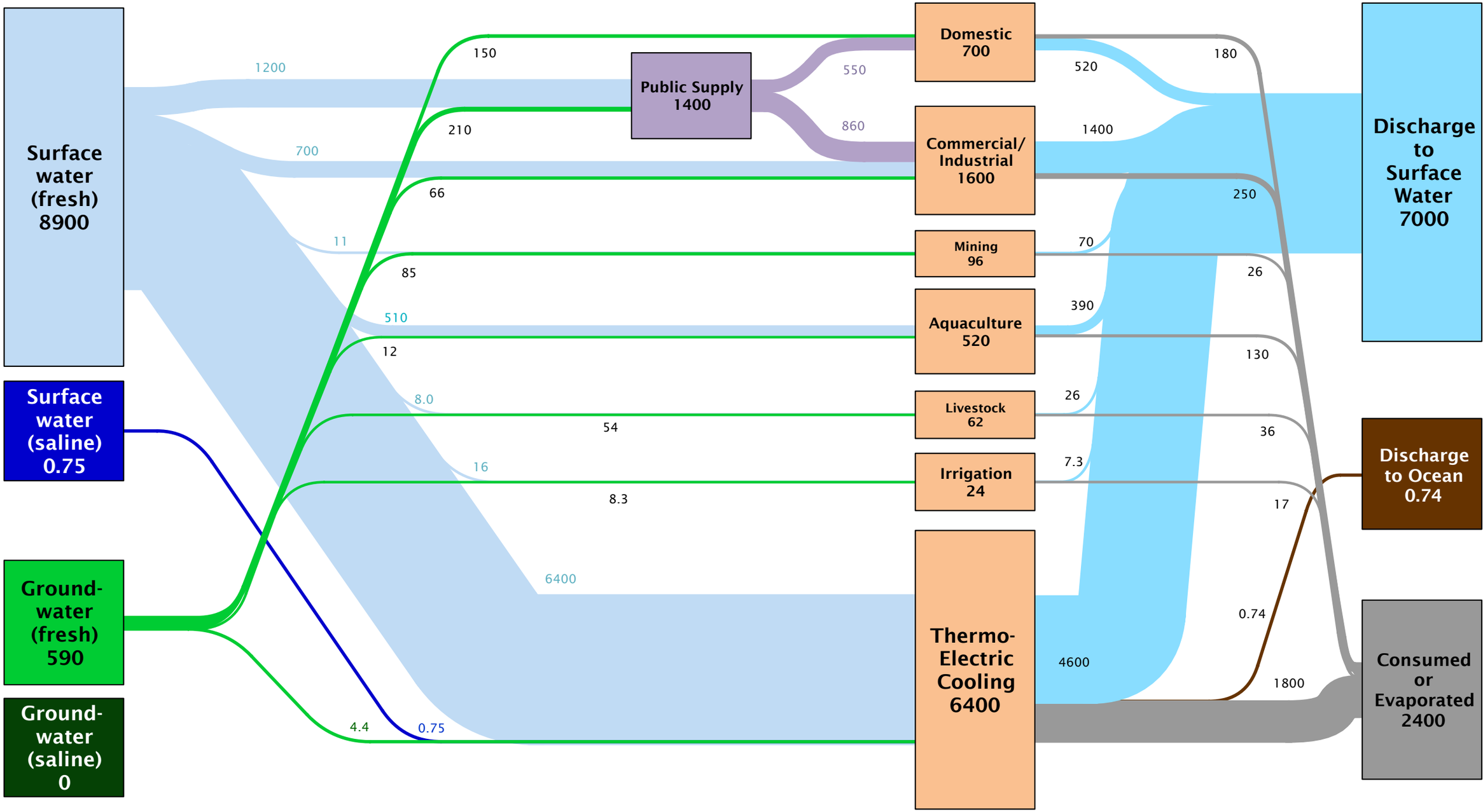
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Oregon Water Flow in 2005: 7200 Million Gallons/Day



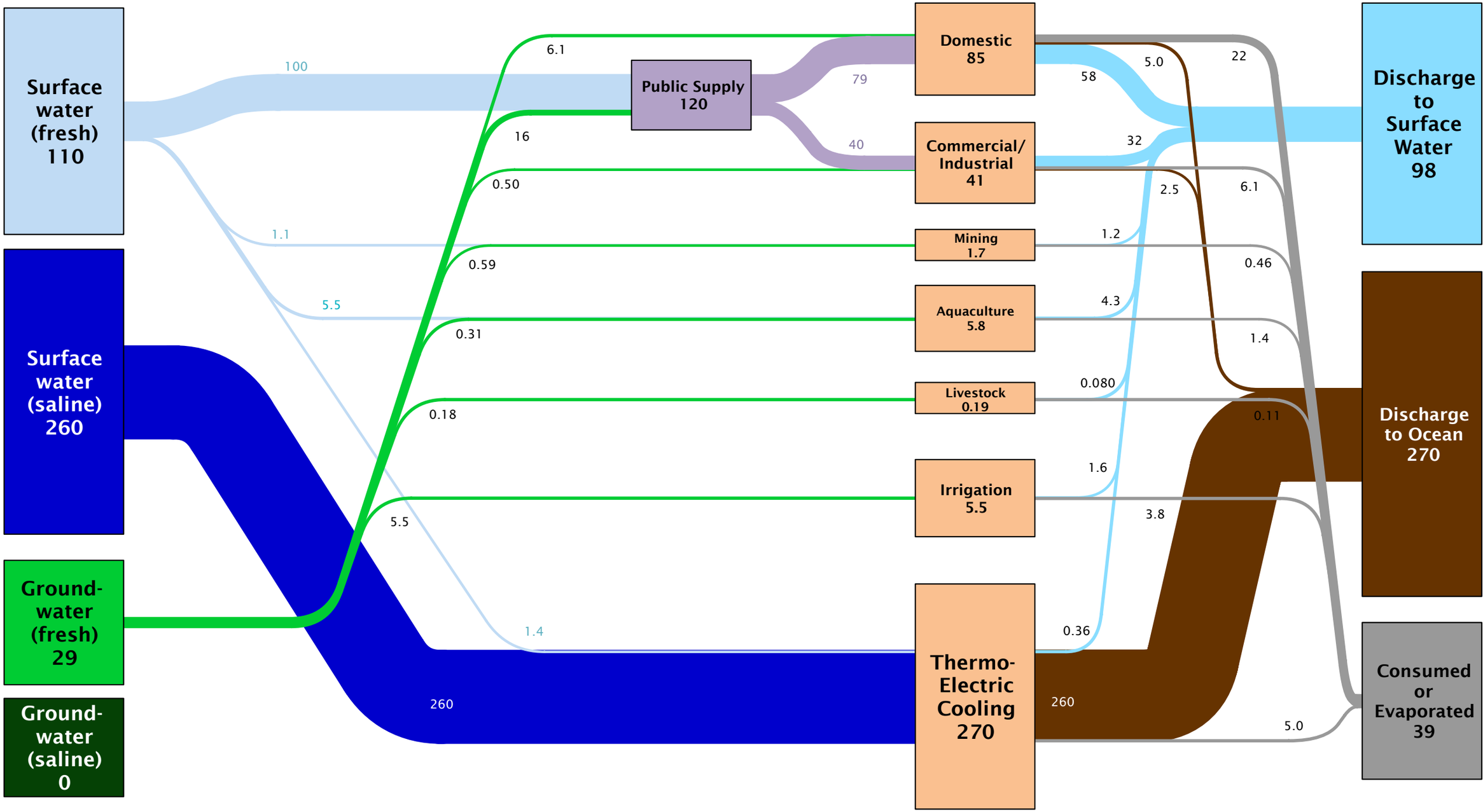
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Pennsylvania Water Flow in 2005: 9500 Million Gallons/Day



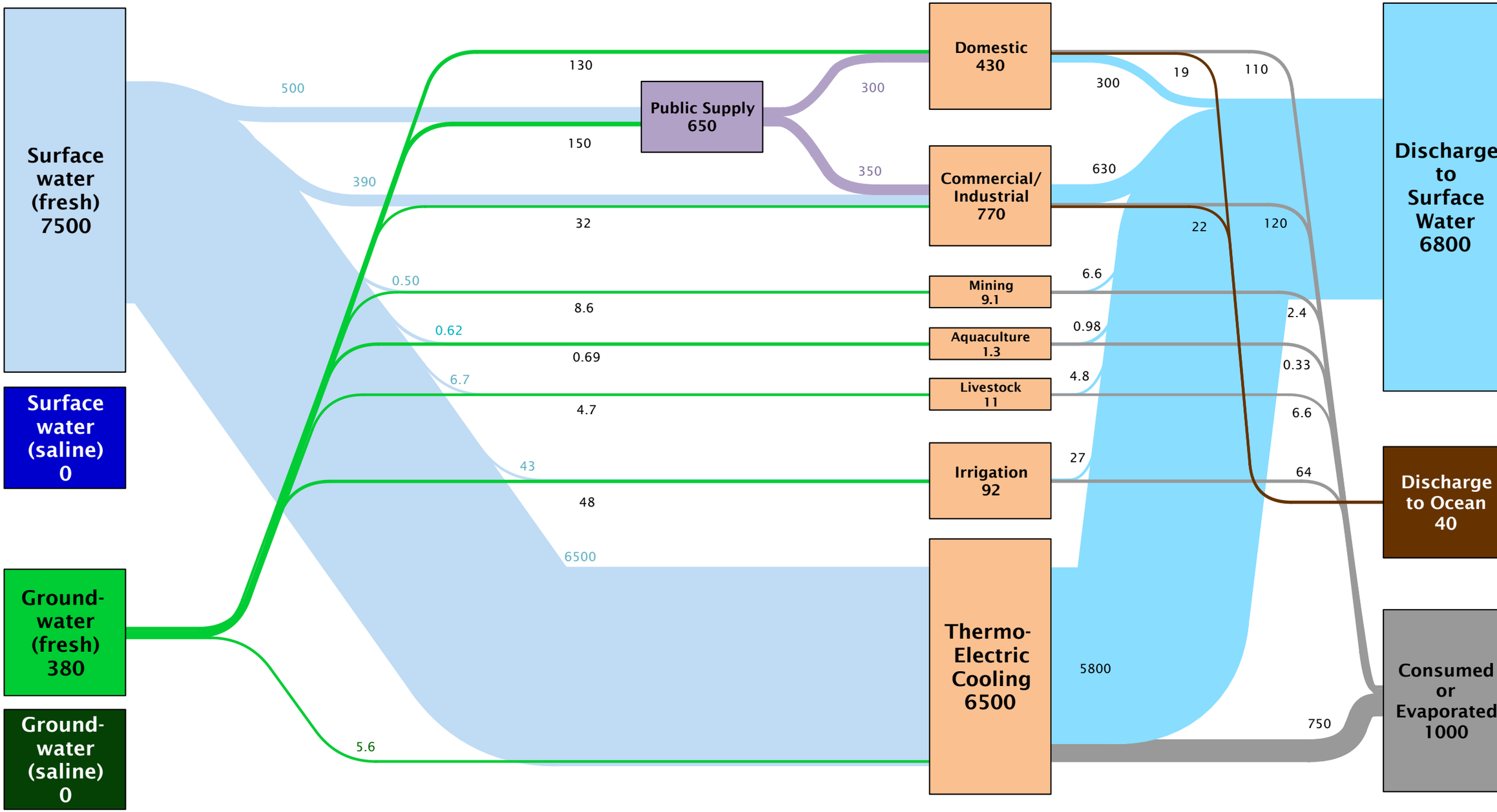
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Rhode Island Water Flow in 2005: 410 Million Gallons/Day



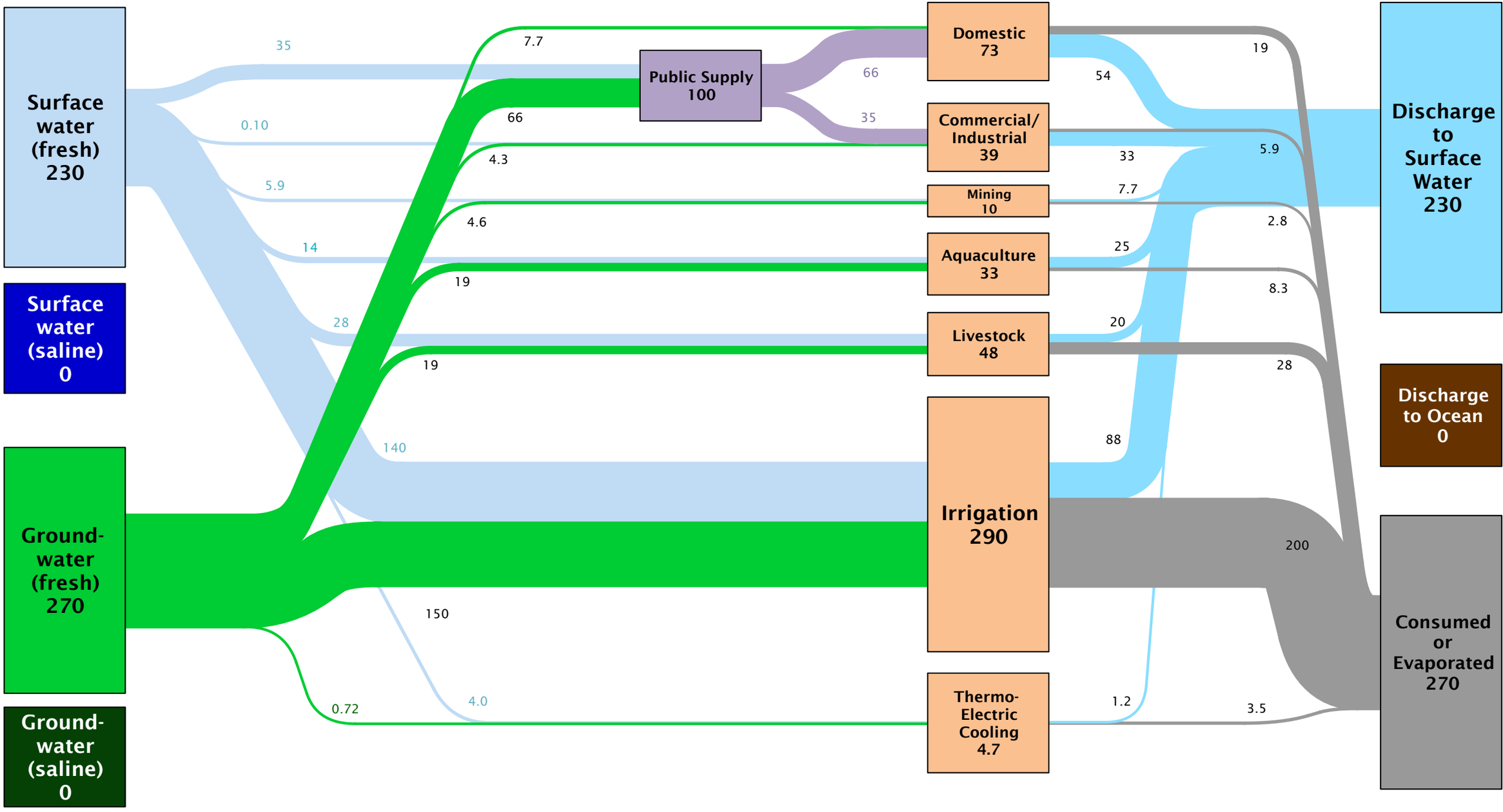
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated South Carolina Water Flow in 2005: 7800 Million Gallons/Day



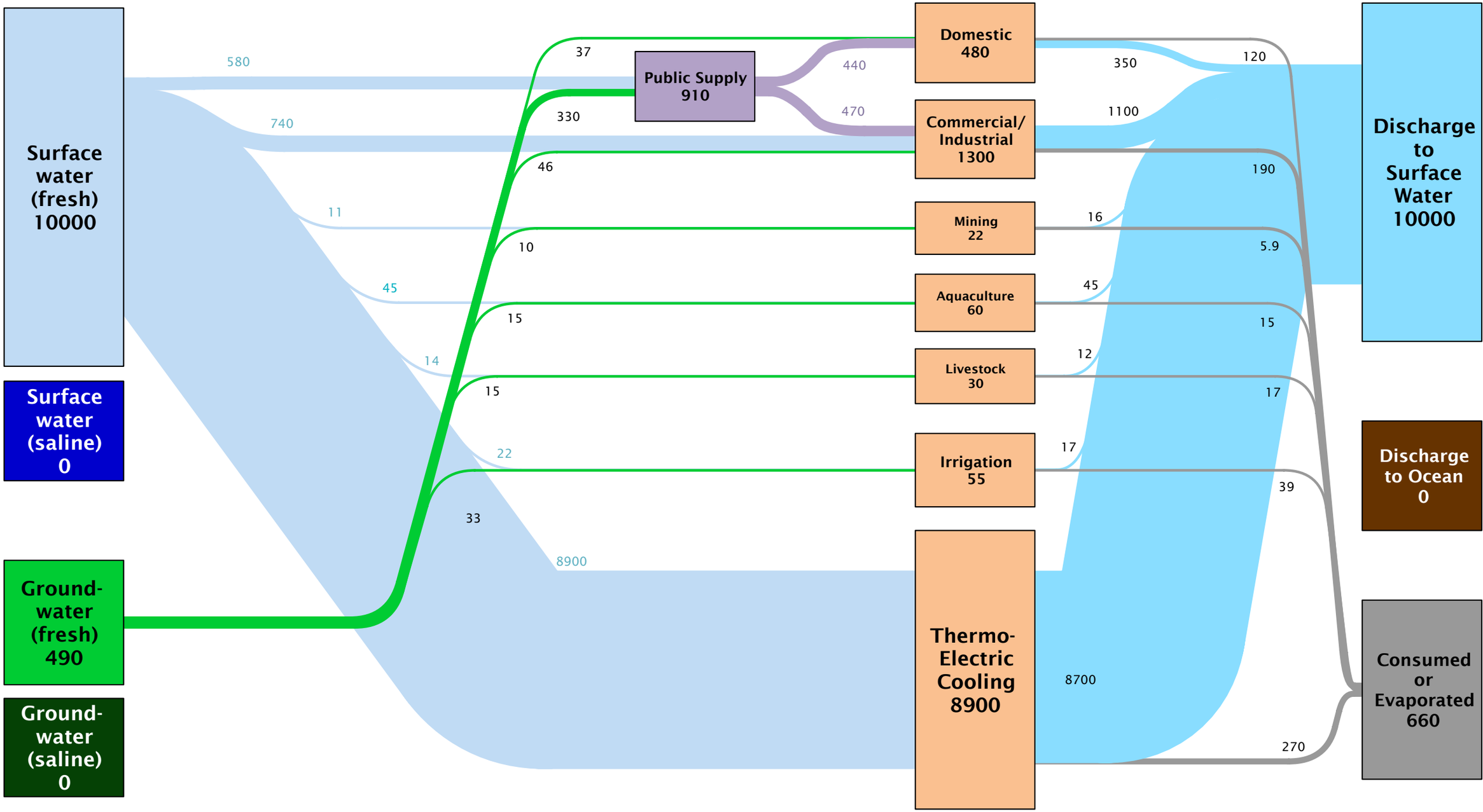
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated South Dakota Water Flow in 2005: 500 Million Gallons/Day



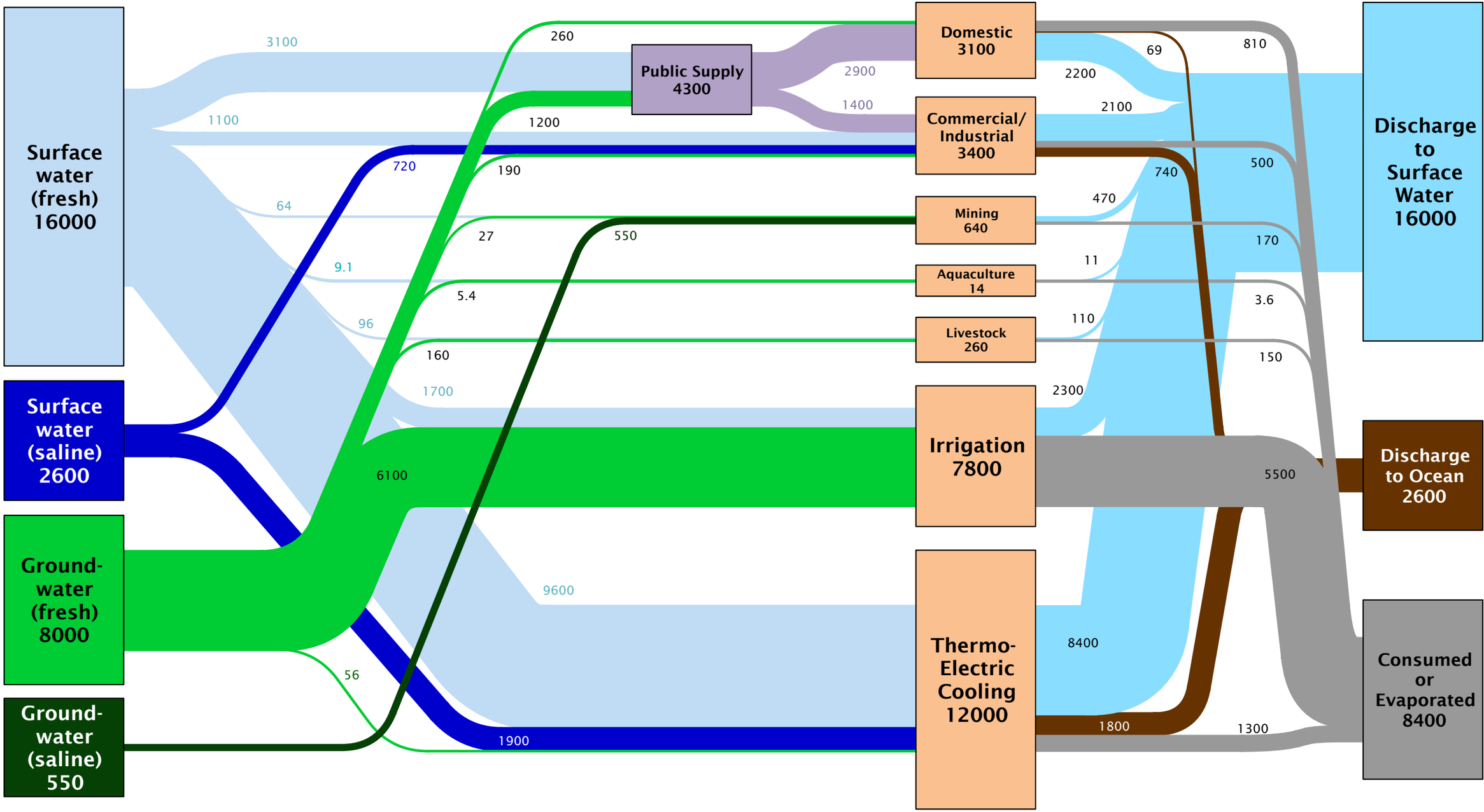
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Tennessee Water Flow in 2005: 11000 Million Gallons/Day



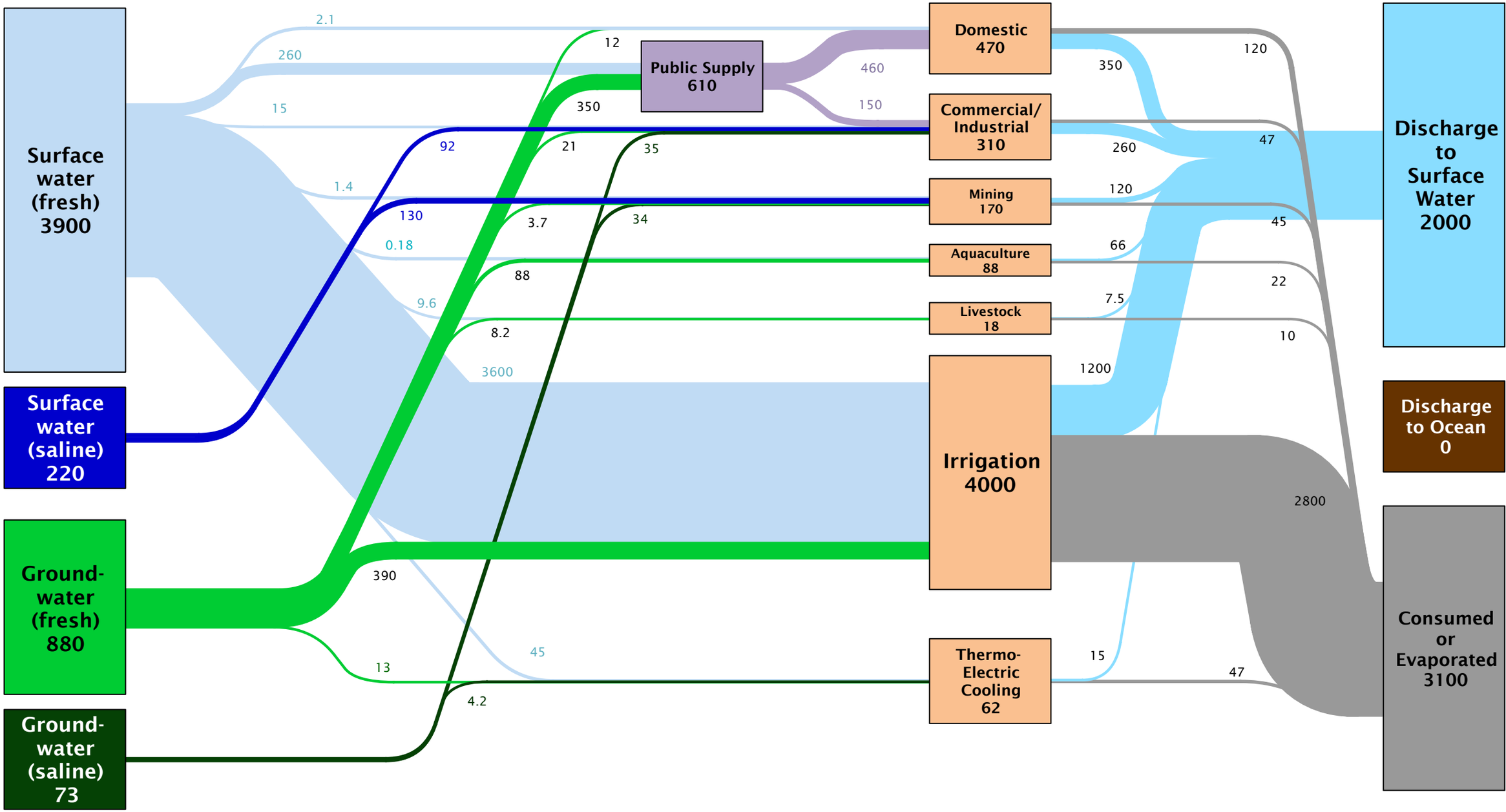
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Texas Water Flow in 2005: 27000 Million Gallons/Day



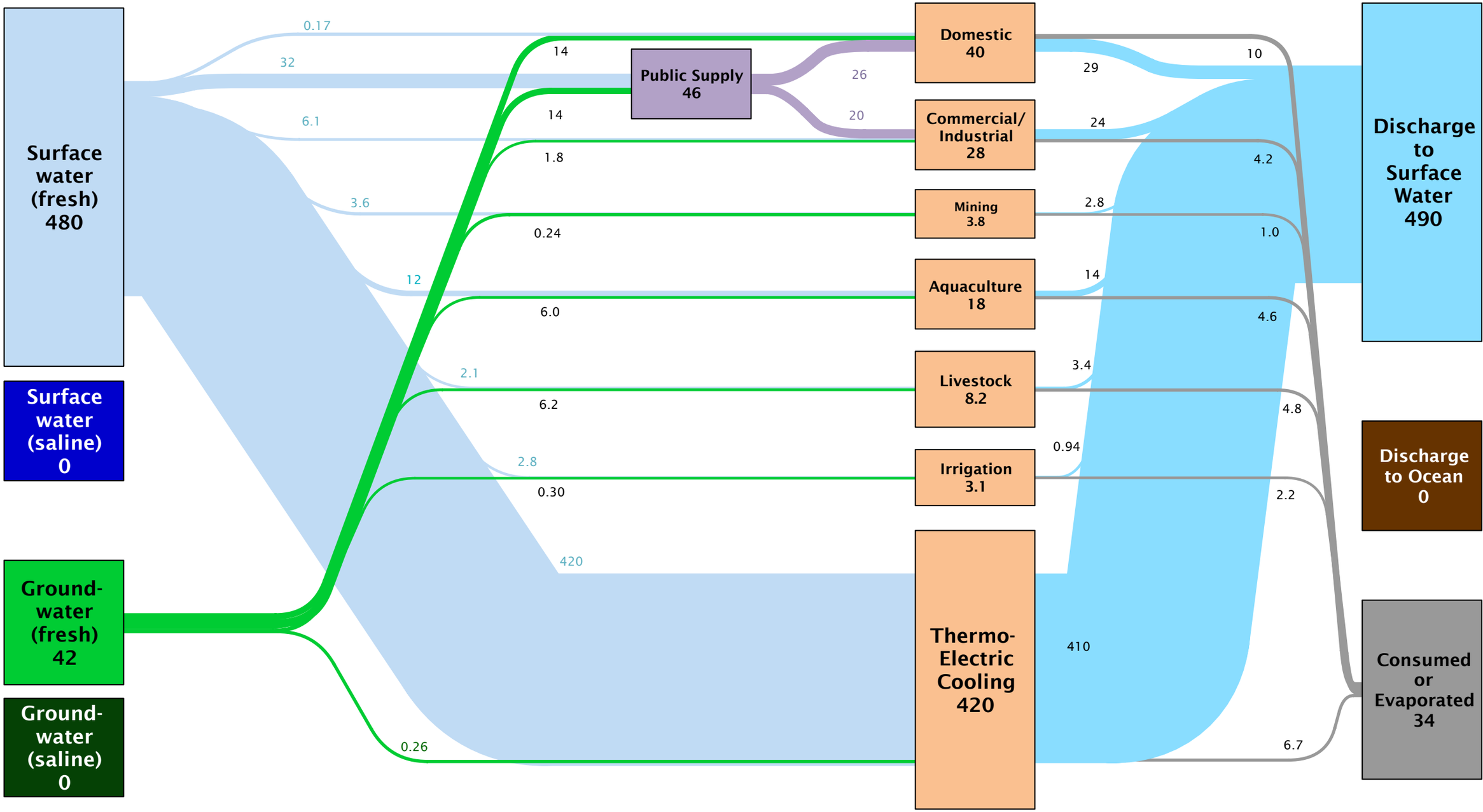
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Utah Water Flow in 2005: 5100 Million Gallons/Day



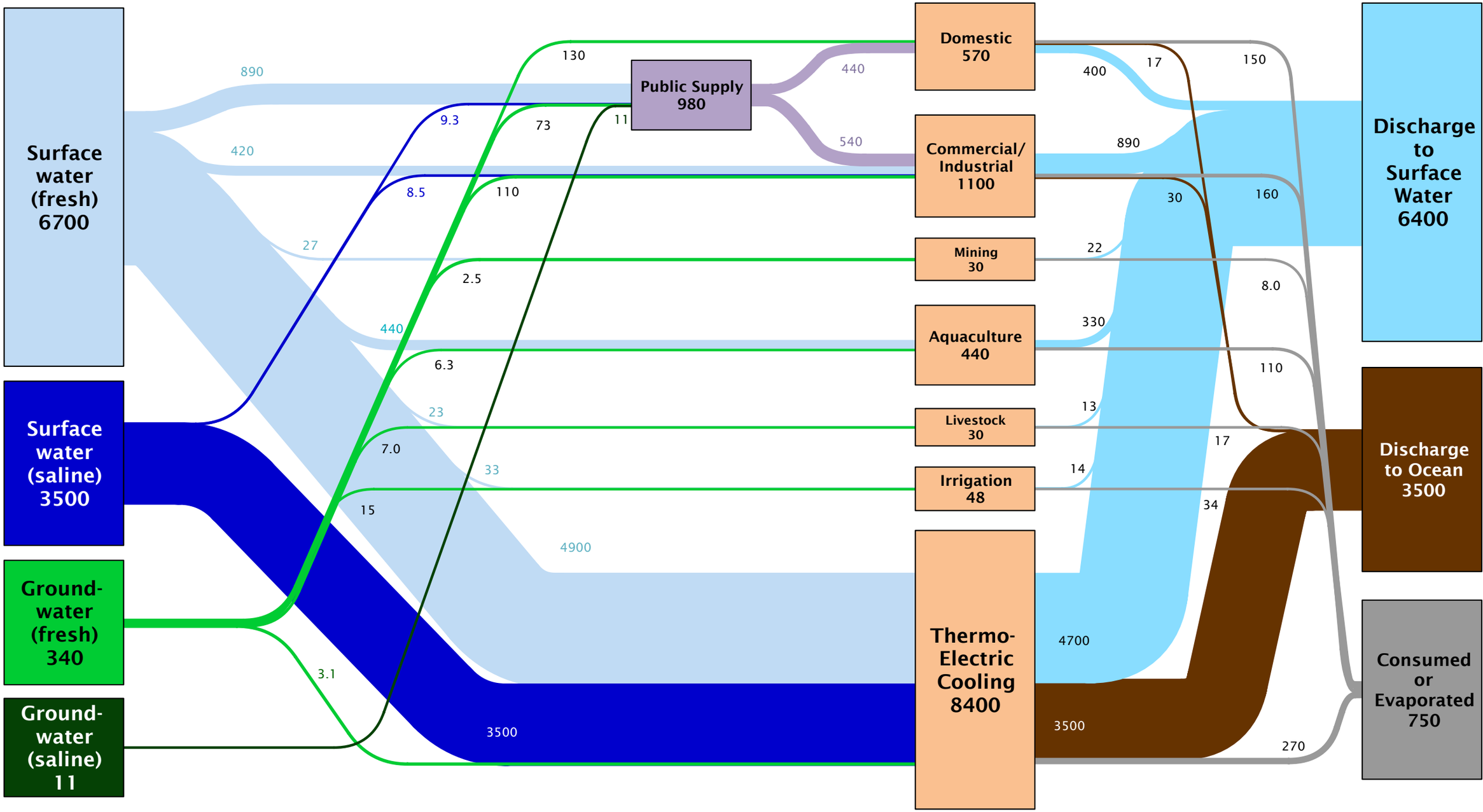
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Vermont Water Flow in 2005: 520 Million Gallons/Day



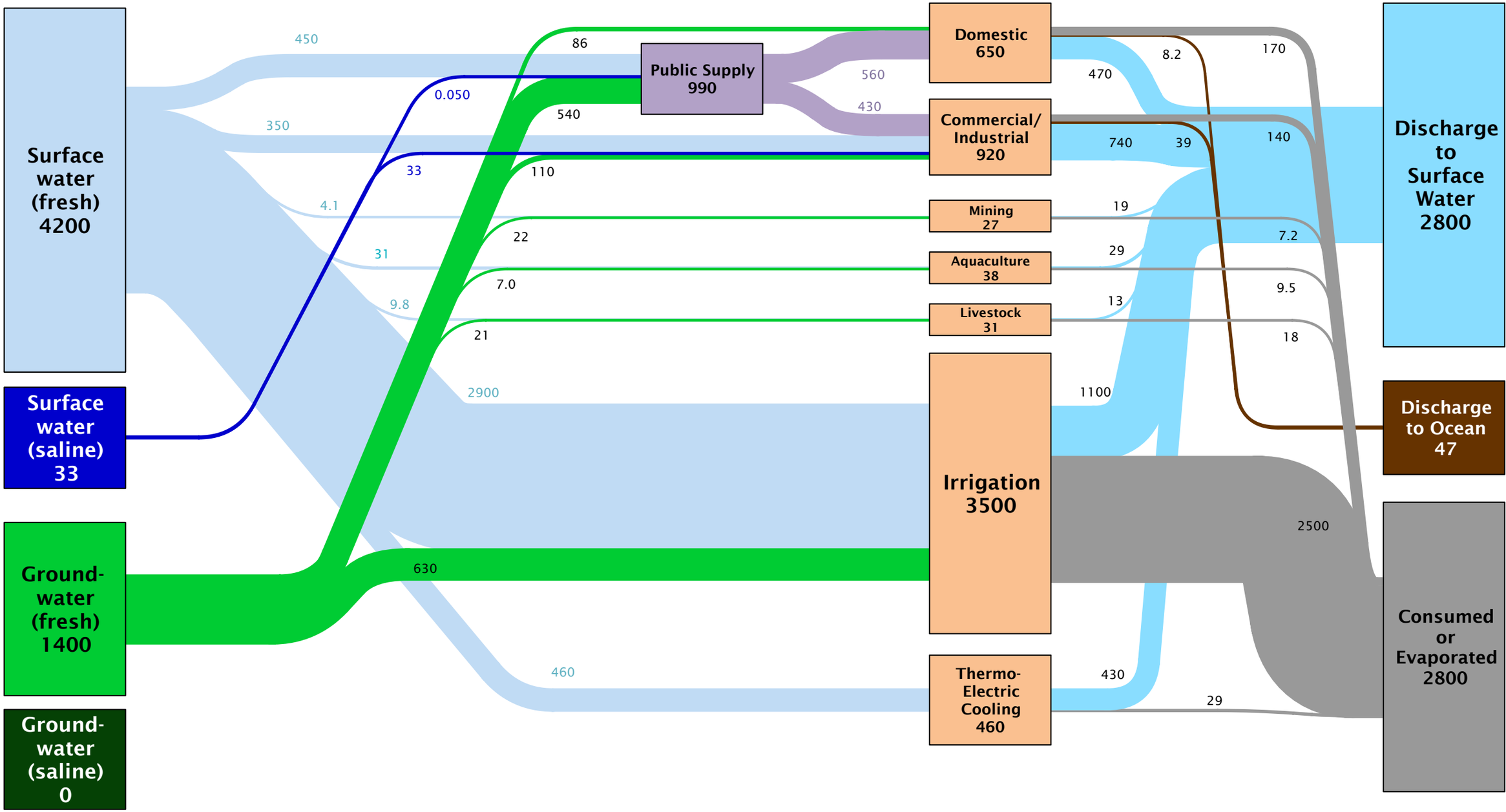
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Virginia Water Flow in 2005: 11000 Million Gallons/Day



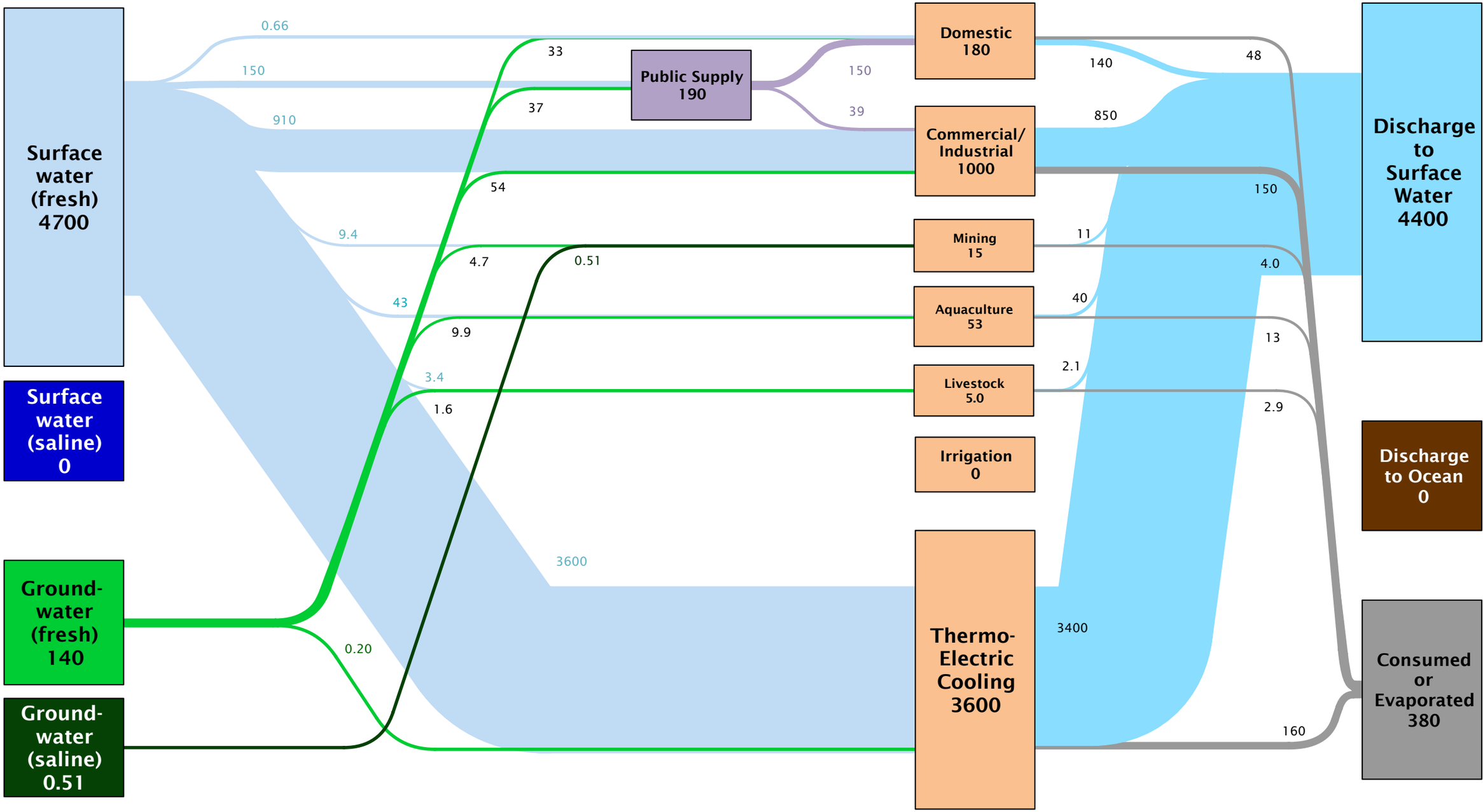
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Washington Water Flow in 2005: 5600 Million Gallons/Day



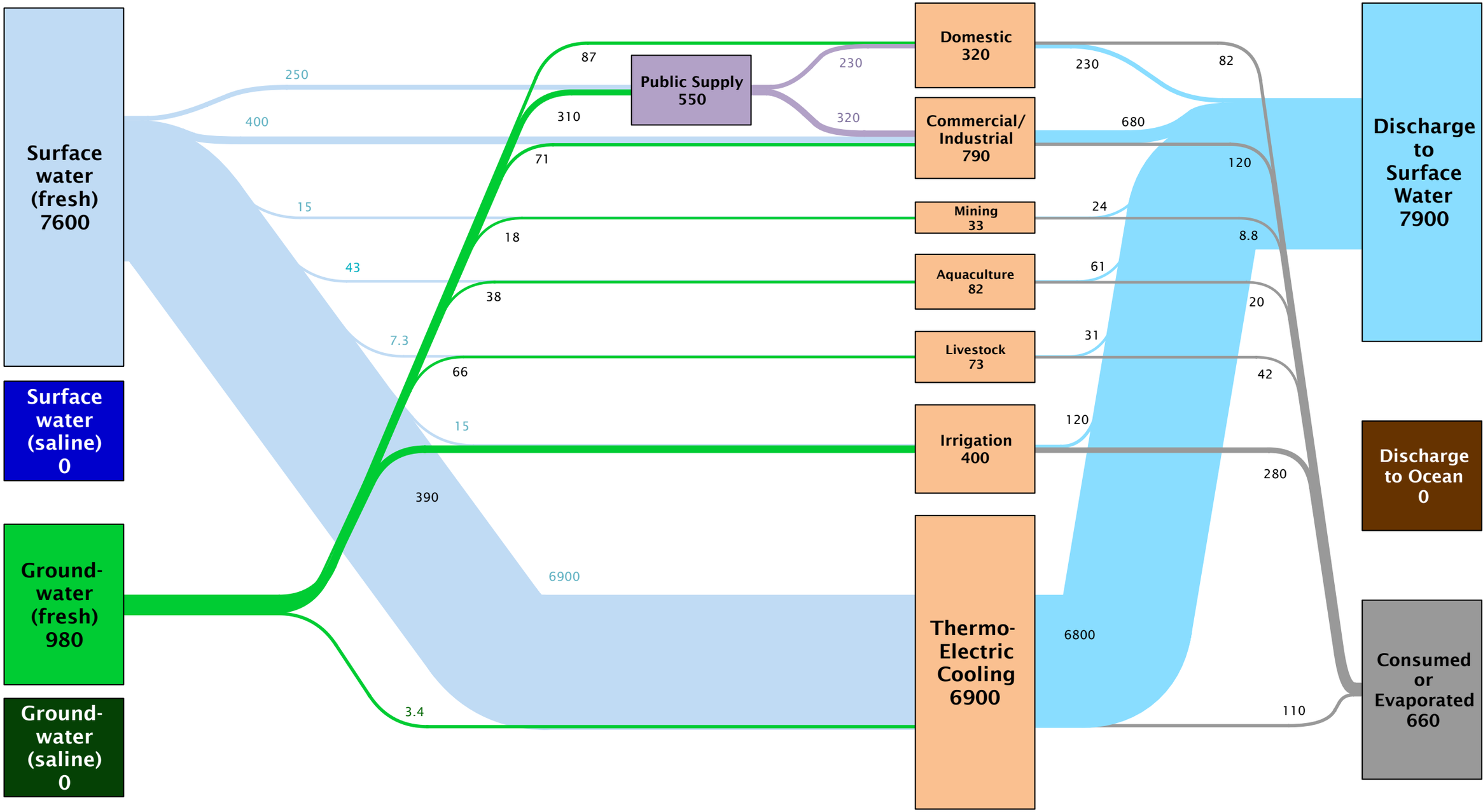
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated West Virginia Water Flow in 2005: 4800 Million Gallons/Day



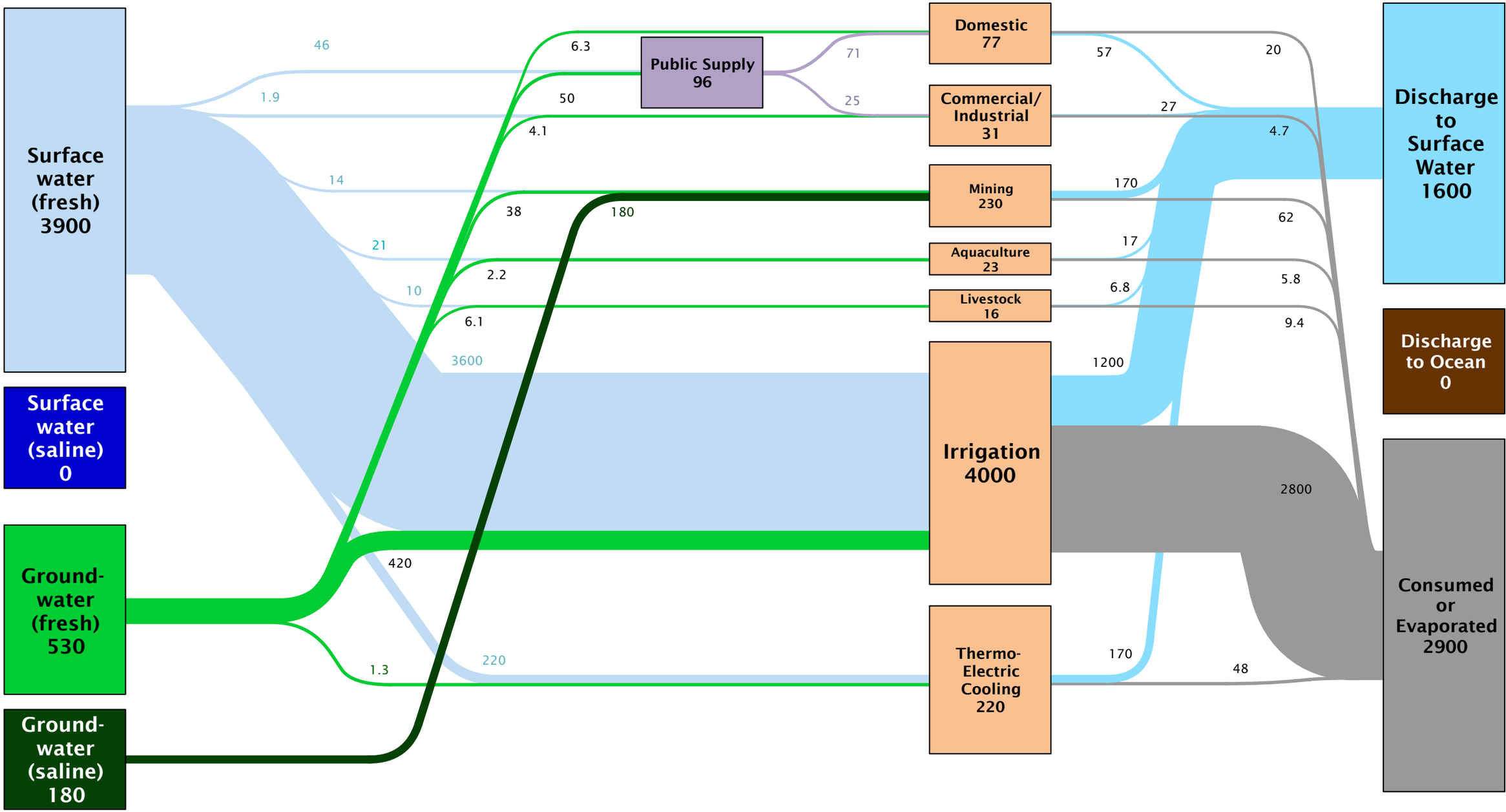
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Wisconsin Water Flow in 2005: 8600 Million Gallons/Day



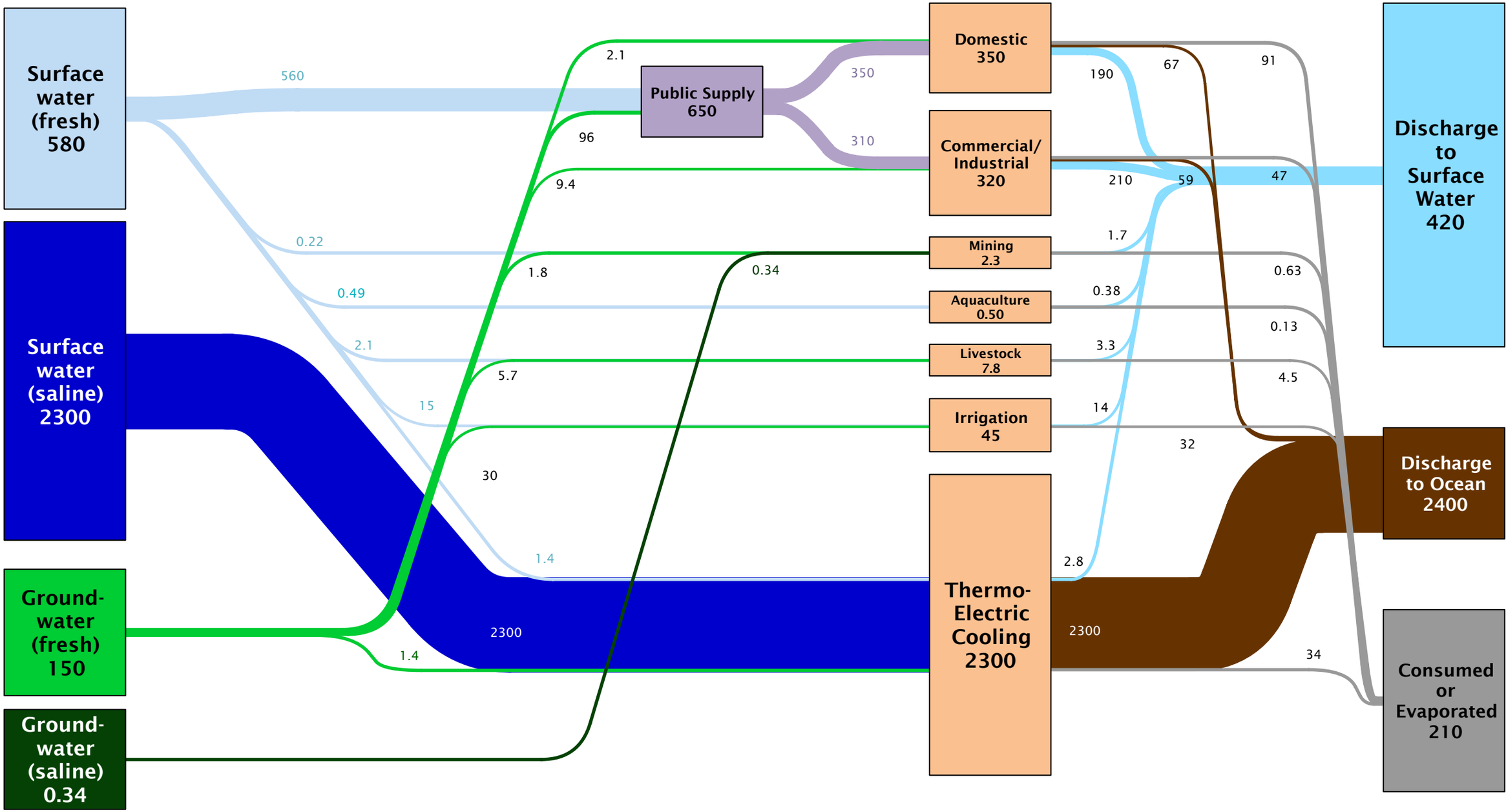
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Wyoming Water Flow in 2005: 4600 Million Gallons/Day



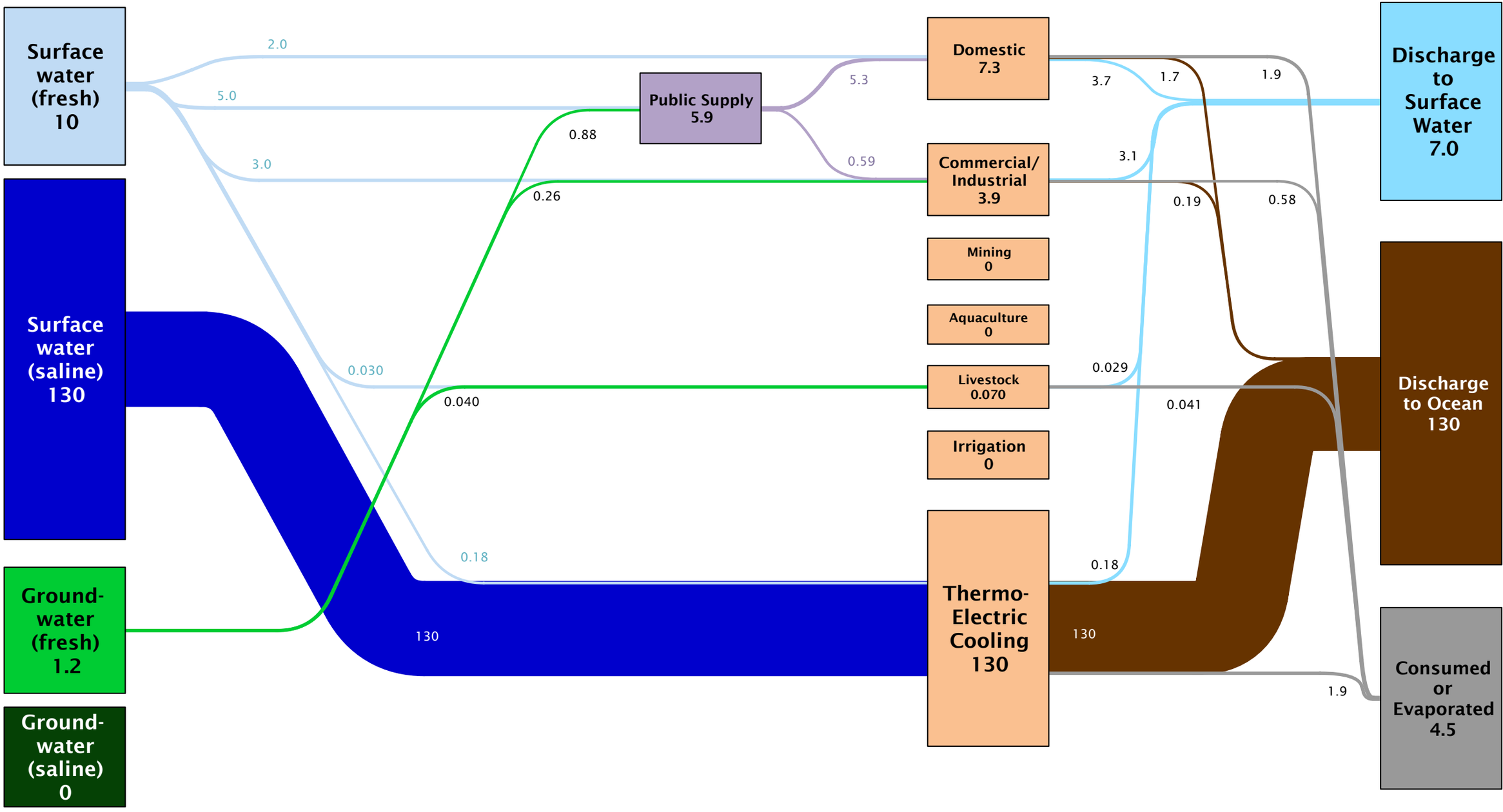
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Puerto Rico Water Flow in 2005: 3000 Million Gallons/Day



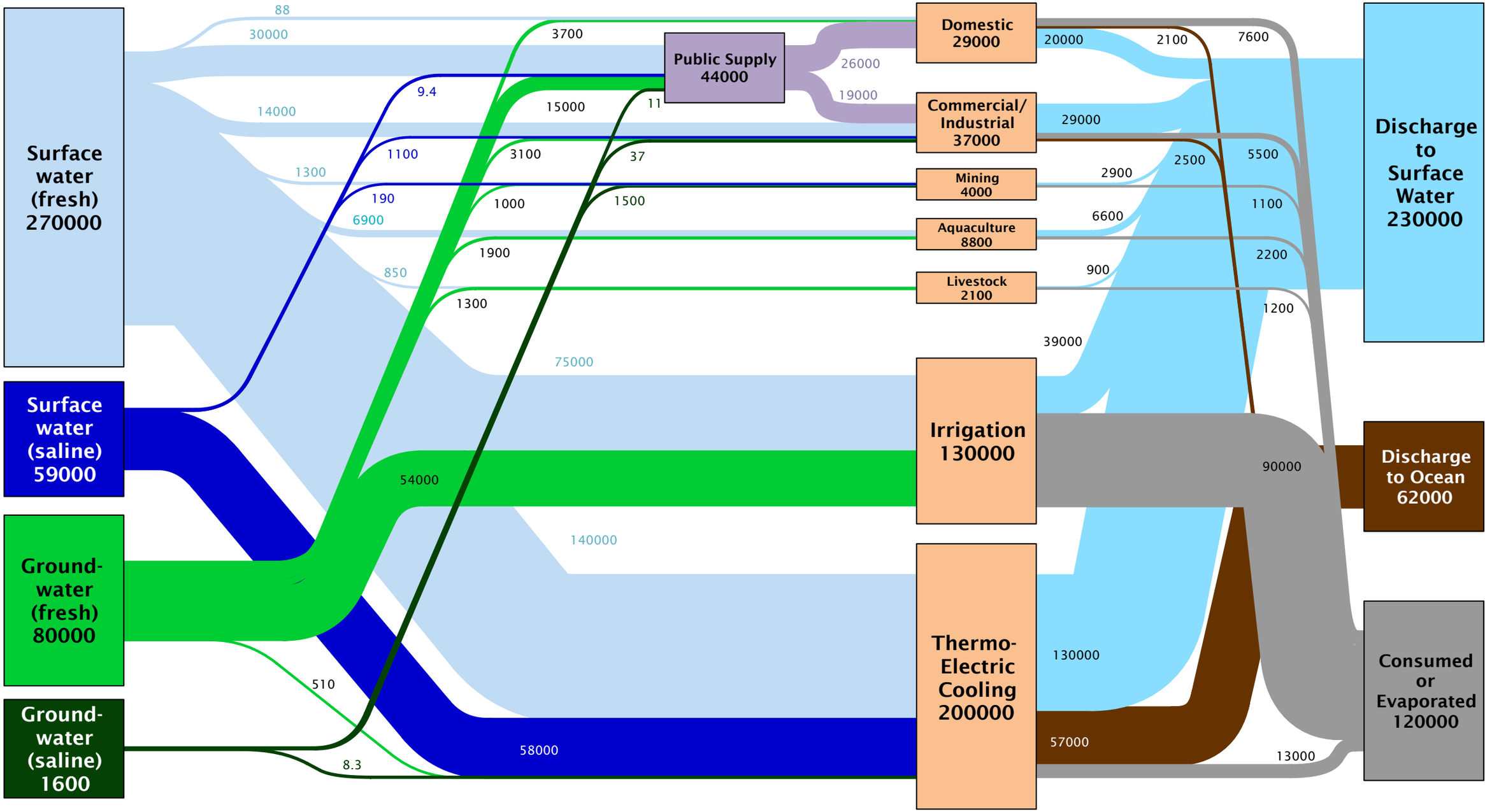
Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated Virgin Islands Water Flow in 2005: 140 Million Gallons/Day



Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772.

Estimated United State Water Flow in 2005: 410000 Million Gallons/Day



Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-475772

Analysis

Fundamental to this analysis is the assumption that water use can be accurately traced from resource to distribution network to use by sector to disposition. There are fairly large uncertainties with respect to the actual amount of water withdrawn, consumed, and returned; and there are many instances where water disposed as "return flow" is immediately withdrawn by another user. Such arrangements can make water accounting difficult and the USGS is to be commended for its extraordinary effort in collecting sparsely and inconsistently recorded data. Assembly of this water flow chart represents a small step in a very long chain of analysis that collapses the cyclic nature of the nation's water infrastructure into a conceptually linear series of unit operations. Unless stated otherwise, all data in this analysis comes from the USGS Water Use report for 2005 (Kenny *et. al.*, 2009). Where water flows have been calculated, the USGS definitions are available in the Data Dictionary included in the appendix of this report.

Flows of water on the flow chart were calculated as follows:

Withdrawals:
USGS directly reports the total withdrawals from each of the four available water resources.

Public Supply:
Public Supply represents the municipally managed distribution network for water. This network obtains its water from all four water resources, but uses very little saline water (desalination of seawater and groundwater for municipal use is growing rapidly, but represents less than 0.05% of public supply). The public supply delivers water to the domestic and commercial/industrial sectors.

USGS directly reports the total water withdrawn from each resource to the public supply.

USGS directly reports the water delivered from the public supply to the domestic sector. USGS does not report how the remainder of public supply is apportioned. In this analysis, it is assumed that all water withdrawn for public supply (PS-Wtotl) that is not delivered to the domestic sector (DO-PSDel) is delivered to the commercial/industrial sector (PS-CI). For the purposes of this analysis, the commercial sector includes commercial and light industrial entities, municipalities, golf courses, and "own use" by the public supply sector.

```
PS-CI = PS-Wtotl - DO-PSDel
```

Domestic
USGS reports the withdrawals of fresh surface-water and groundwater by the domestic sector. These withdrawals comprise privately owned water resources (primarily individual wells), generally in areas not served by public supply. There are no reported direct uses of saline water in the domestic sector.

USGS reports directly the deliveries of public supplied water to the domestic sector.

USGS no longer reports the disposition of domestic water. This analysis assumes that of the total amount of water withdrawn for the domestic sector (DO-TOTAL), the percentage consumed by the domestic sector (DO-Consum) has not changed substantially from 26%, the value reported in 1995 (Solley *et. al.*, 1999).

$$DO\text{-}Consum = 26\% * DO\text{-}TOTAL$$

The remainder of domestic water is returned to surface waters such as rivers, lakes, or oceans. It is difficult to find comprehensive data on domestic wastewater discharge to saline surface waters (DO-SaSW). Therefore, a percentage is calculated for each state on the basis of coastal populations from the reported domestic water delivered from the public supply (%DO-> SaSW(STATE)). For landlocked states, the amount of water supplied by and returned to the ocean is zero. For states with coastal boundaries, the estimation is based on data collected in California.

It is estimated that 1.35 billion gallons per day are discharged by municipal wastewater treatment in California (Heal the Ocean, 2010). This quantity represents approximately 20% of California's public supply (% DO-SaSW(CA)). As reported in the 2006 census 62% of the total population of California (%Coast(CA)) (US Places, 2010) live in coastal counties. The percentage of the population living in coastal counties in each state can similarly be calculated (%Coast(STATE)).

It is assumed that the ratio of public supply water discharge to the ocean to percent coastal population remains consistent for every other coastal state and can be used to find the percent of a state's public water supply discharged to saline surface water. For example, Alaska has a percent coastal population of 80% and its percentage of the public supply water discharged to the ocean is found by multiplying its 80% coastal population percentage by the 20% of the public supply water discharged to the ocean in California and dividing by the 62% the California coastal population percentage.

$$\%DO\text{-}SaSW(STATE) = \frac{\%DO\text{-}SaSW(CA) * \%Coast(STATE)}{\%Coast(CA)}$$

The flow of domestic water discharged to saline surface waters (DO-SaSW) is then calculated from the total domestic water delivered from the public supply.

$$DO\text{-}SaSW = \%DO\text{-}SaSW(STATE) * DO\text{-}PSDel$$

Any domestic water not consumed or discharged to the ocean is returned to fresh surface waters (DO->FrSW).

$$DO\text{-}FrSW = DO\text{-}TOTAL - (DO\text{-}Consum + DO\text{-}SaSW)$$

Commercial/Industrial

USGS reports directly the withdrawals of all four water resources by the industrial sector.

Because the latest edition of Circular 1344 does not describe commercial water use, this analysis combines commercial and industrial water uses. The total use by the commercial/industrial sector (CI-Totl) therefore includes the total industrial withdrawal (IN-Wtotl) plus the portion of public supply that is not delivered to domestic consumers (PS-Wtotl – DO-PSDel).

```
CI-Totl = IN-Wtotl + PS-Wtotl - DO-PSDel
```

USGS no longer reports the disposition of water by the commercial and industrial sectors. In 1995, the percentages of withdrawn water consumed by the commercial and industrial sectors (CI- Consum) were reported to be 14% and 15%, respectively. In this analysis, we assume that the composite commercial/industrial water consumption fraction is 15% (Solley *et. al.*, 1999). This fraction includes the 1.5% of saline surface withdrawals by industry that are lost to consumption/evaporation (see below).

```
CI-Consum = CI-Totl * 15%
```

The disposition of water returned to the ocean from the commercial and industrial sectors (CI-SaSW) is similar to the residential sector and calculated as follows: a percentage of public supply deliveries to the commercial/industrial sector are returned to municipalities that discharge water into the ocean based on the coastal population of the state. Additionally, it is assumed that 1.5% of the saline surface withdrawals are lost to consumption or evaporation, and the remaining 98.5% are returned to the ocean.

```
CI-SaSW = (PS-CI * %DO-SaSW(STATE)) + (IN-WSWSa * 98.5%)
```

The remainder of commercial/industrial water is returned to bodies of freshwater (CI- FrSW).

```
CI-FSW = CI-Totl – (CI-Consum + CI-SaSW)
```

Mining

USGS directly reports the withdrawals of all four water resources by the mining sector. The mining sector does not take water deliveries from public supplies.

In 1995, USGS estimates that of the total amount of water used in mining (MI-Totl) 27% is consumptive (MI- Consum) (Solley *et. al.*, 1999), and the remainder is returned to surface bodies of water (MI-FrSW). This analysis assumes that no water is returned from the mining sector to the ocean.[1]

```
MI-Consum = 27% * MI-Totl

MI-FrSW = MI-Totl – MI-Consum
```

Aquaculture

USGS reports directly the withdrawals of fresh surface-water and fresh groundwater for use in aquaculture. No saline water use is reported for aquaculture.

Of the total amount of water used in aquaculture (LA-Totl), the percentage consumed (LA- Consum) varies from 20% to 55% (Boyd *et. al.*, 2008). This analysis assumes that on average, 25% of water used in aquaculture is consumed. It is assumed that no freshwater used in aquaculture is returned directly to the ocean as the remaining water is returned to surface waters (LA- FrSW).

```
LA-Consum = 25% * LA-Totl

LA-FrSW = LA-Totl – LA-Consum
```

Livestock

USGS reports directly the withdrawals of fresh surface-water and fresh groundwater for use by livestock. No saline water use is reported by livestock.

Of the total amount of water used in livestock applications (LI-Totl), 58% was estimated as consumed in 1995 (LI- Consum) (Solley *et. al.*, 1999). This percentage is assumed to remain unchanged for this analysis of water flow in 2005. It is assumed that no water used for livestock is returned to the ocean. Therefore, the water returned to fresh surface water from livestock use (LI-FrSW) is the amount that which is not consumed by the livestock.

```
LI-Consum = 58% * LI-Totl

LI-FrSW = LI-Totl – LI-Consum
```

[1] It is likely that significant quantities of seawater are withdrawn and returned to the ocean in offshore drilling processes. These withdrawals are not included in the USGS accounting.

Irrigation

USGS reports directly the withdrawals of fresh surface-water and fresh groundwater for use in irrigation. No saline water use is reported by irrigation.

In 1995, it was estimated that 61% of irrigation water use was consumptive, 20% was returned and 19% was lost in conveyance (Solley *et. al.*, 1999). It is unclear whether conveyance losses should be accounted for as return flow (if the "lost" water remains in the watershed or if it evaporates). For this analysis, we assume that some progress has been made in irrigation efficiency (increasing the consumptive percentage in irrigation) and that some conveyance losses can be considered to be consumptive. Of the total amount of water used in irrigation (IR-Totl), the total consumptive percentage for irrigation is assumed to be 70% (IR- Consum). It is assumed that no irrigation water is returned to the ocean. Therefore, the water returned to fresh surface water from irrigation (IR-FrSW) is the amount that is not consumed by irrigation.

```
IR-Consum = 70% * IR-Totl

IR-FrSW = IR-Totl – IR-Consum
```

Thermoelectric Cooling[2,3]

USGS reports directly the withdrawals of all four water resources for use in thermoelectric cooling. The thermoelectric sector does not take deliveries from public supplies.

USGS reports separately the quantities of each water resource withdrawn for once-through and recirculating power plants, which together total the amount of water used in thermoelectric cooling (PT-Totl). Power plants cooled with ocean water that have once-through cooling designs and are assumed to return 98.5% of saline surface- and groundwater used in thermoelectric cooling (PO-WSaTo) to the ocean while the remainder is consumed. Water returned to the ocean from recirculating power plants using saline surface-and groundwater (PC-WSaTo) is assumed to be 25% of that withdrawn from the ocean while the remaining 75% is consumed during the process. These two calculated values are summed to represent the total amount of water returned to the ocean from thermoelectric cooling processes (PT->SaSW).

```
PT-SaSW = 98.5% * PO-WSaTo + 25% * PC-WSaTo
```

[2] There are two discrepancies between the data as reported by the USGS and the flow charts depicted in this report. The first is that water use in Kentucky has been over-reported for power plants using recirculating cooling loops. An example of the data modification is for the thermoelectric water usage for McCracken County, Kentucky, where the water use was reported for a recirculating power plant. However, the major power plant in McCracken County is the TVA Shawnee Power Plant, a power plant that utilizes once-through cooling (Dziegielewski, 2006). Therefore, the power plant water usage for this county has been altered to indicate once-through cooling.

[3] The second discrepancy occurs in Hawaii where the thermoelectric water withdrawals for Hawaii were reported as originating from saline groundwater. From geographic examination of the location of the major power plants, the likely source of thermoelectric cooling water is saline surface-water and the water flows are represented in these flowcharts as such.

The total flow of water consumed through thermoelectric processes (PT- Consum) is the sum of the remainders from power plants with once-through cooling designs (PO-WTotl) and power plant with recirculating cooling designs (PC-WTotl).

```
PT-Consum = 1.5% * PO-WTotl + 75% * PC-WTotl
```

The remainder of all water withdrawn by the thermoelectric sector is returned to the surface (PT- FrSW).

```
PT-FrSW = PT-Totl – (PT-SaSW + PT-Consum)
```

Conclusion

The flow charts described in this report are compact depictions of the national water use data contained in the USGS report on water use in the United States in 2005. These diagrams are available at: http://flowcharts.llnl.gov

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Appendix: Selections from Data Dictionary

(reproduced from the excel file available at http://water.usgs.gov/watuse/data/2005/)

USGS defined terms

PS-WGWFr	Public Supply, groundwater withdrawals, fresh, in Mgal/d
PS-WGWSa	Public Supply, groundwater withdrawals, saline, in Mgal/d
PS-WGWTo	Public Supply, groundwater withdrawals, total, in Mgal/d
PS-WSWFr	Public Supply, surface-water withdrawals, fresh, in Mgal/d
PS-WSWSa	Public Supply, surface-water withdrawals, saline, in Mgal/d
PS-WSWTo	Public Supply, surface-water withdrawals, total, in Mgal/d
PS-WFrTo	Public Supply, total withdrawals, fresh, in Mgal/d
PS-WSaTo	Public Supply, total withdrawals, saline, in Mgal/d
PS-Wtotl	Public Supply, total withdrawals, total (fresh+saline), in Mgal/d
DO-WGWFr	Domestic, self-supplied groundwater withdrawals, fresh, in Mgal/d
DO-WSWFr	Domestic, self-supplied surface-water withdrawals, fresh, in Mgal/d
DO-WFrTo	Domestic, total self-supplied withdrawals, fresh, in Mgal/d
DO-PSDel	Domestic, deliveries from Public Supply, in Mgal/d
DO-TOTAL	Domestic, total use (withdrawals + deliveries)
IN-WGWFr	Industrial, self-supplied groundwater withdrawals, fresh, in Mgal/d
IN-WGWSa	Industrial, self-supplied groundwater withdrawals, saline, in Mgal/d
IN-WGWTo	Industrial, self-supplied groundwater withdrawals, total, in Mgal/d
IN-WSWFr	Industrial, self-supplied surface-water withdrawals, fresh, in Mgal/d
IN-WSWSa	Industrial, self-supplied surface-water withdrawals, saline, in Mgal/d
IN-WSWTo	Industrial, self-supplied surface-water withdrawals, total, in Mgal/d
IN-WFrTo	Industrial, self-supplied total withdrawals, fresh, in Mgal/d
IN-WSaTo	Industrial, self-supplied total withdrawals, saline, in Mgal/d
IN-Wtotl	Industrial, self-supplied total withdrawals, total (fresh+saline), in Mgal/d
IR-WGWFr	Irrigation, groundwater withdrawals, fresh, in Mgal/d
IR-WSWFr	Irrigation, surface-water withdrawals, fresh, in Mgal/d
IR-WFrTo	Irrigation, total withdrawals, fresh, in Mgal/d
IC-WGWFr	Irrigation-Crop, groundwater withdrawals, fresh, in Mgal/d
IC-WSWFr	Irrigation-Crop, surface-water withdrawals, fresh, in Mgal/d
IC-WFrTo	Irrigation-Crop, total withdrawals, fresh, in Mgal/d
IC-IrSpr	Irrigation-Crop, acres irrigated, sprinkler, in thousands
IC-IrMic	Irrigation-Crop, acres irrigated, microirrigation, in thousands
IC-IrSur	Irrigation-Crop, acres irrigated, surface (flood), in thousands
IC-IrTot	Irrigation-Crop, acres irrigated, total, in thousands
LS-WGWFr	Livestock, groundwater withdrawals, fresh, in Mgal/d
LS-WSWFr	Livestock, surface-water withdrawals, fresh, in Mgal/d
LS-WFrTo	Livestock, total withdrawals, fresh, in Mgal/d
LA-WGWFr	Aquaculture, groundwater withdrawals, fresh, in Mgal/d
LA-WSWFr	Aquaculture, surface-water withdrawals, fresh, in Mgal/d
LA-WFrTo	Aquaculture, total withdrawals, fresh, in Mgal/d
MI-WGWFr	Mining, groundwater withdrawals, fresh, in Mgal/d
MI-WGWSa	Mining, groundwater withdrawals, saline, in Mgal/d
MI-WGWTo	Mining, groundwater withdrawals, total, in Mgal/d
MI-WSWFr	Mining, surface-water withdrawals, fresh, in Mgal/d
MI-WSWSa	Mining, surface-water withdrawals, saline, in Mgal/d
MI-WSWTo	Mining, surface-water withdrawals, total, in Mgal/d
MI-WFrTo	Mining, total withdrawals, fresh, in Mgal/d
MI-WSaTo	Mining, total withdrawals, saline, in Mgal/d
MI-Wtotl	Mining, total withdrawals, total (fresh+saline), in Mgal/d
PT-WGWFr	Thermoelectric, groundwater withdrawals, fresh, in Mgal/d
PT-WGWSa	Thermoelectric, groundwater withdrawals, saline, in Mgal/d
PT-WGWTo	Thermoelectric, groundwater withdrawals, total, in Mgal/d
PT-WSWFr	Thermoelectric, surface-water withdrawals, fresh, in Mgal/d
PT-WSWSa	Thermoelectric, surface-water withdrawals, saline, in Mgal/d
PT-WSWTo	Thermoelectric, surface-water withdrawals, total, in Mgal/d

USGS defined terms

PT-WFrTo	Thermoelectric, total withdrawals, fresh, in Mgal/d
PT-WSaTo	Thermoelectric, total withdrawals, saline, in Mgal/d
PT-Wtotl	Thermoelectric, total withdrawals, total (fresh+saline), in Mgal/d
PT-Power	Thermoelectric, power generated, in gigawatt-hours
PO-WGWFr	Thermoelectric once-through, groundwater withdrawals, fresh, in Mgal/d
PO-WGWSa	Thermoelectric once-through, groundwater withdrawals, saline, in Mgal/d
PO-WGWTo	Thermoelectric once-through, groundwater withdrawals, total, in Mgal/d
PO-WSWFr	Thermoelectric once-through, surface-water withdrawals, fresh, in Mgal/d
PO-WSWSa	Thermoelectric once-through, surface-water withdrawals, saline, in Mgal/d
PO-WSWTo	Thermoelectric once-through, surface-water withdrawals, total, in Mgal/d
PO-WFrTo	Thermoelectric once-through, total withdrawals, fresh, in Mgal/d
PO-WSaTo	Thermoelectric once-through, total withdrawals, saline, in Mgal/d
PO-WTotl	Thermoelectric once-through, total withdrawals, total, in Mgal/d
PO-Power	Thermoelectric once-through, power generated, in gigawatt-hours
PC-WGWFr	Thermoelectric recirculation, groundwater withdrawals, fresh, in Mgal/d
PC-WGWSa	Thermoelectric recirculation, groundwater withdrawals, saline, in Mgal/d
PC-WGWTo	Thermoelectric recirculation, groundwater withdrawals, total, in Mgal/d
PC-WSWFr	Thermoelectric recirculation, surface-water withdrawals, fresh, in Mgal/d
PC-WSWSa	Thermoelectric recirculation, surface-water withdrawals, saline, in Mgal/d
PC-WSWTo	Thermoelectric recirculation, surface-water withdrawals, total, in Mgal/d
PC-WFrTo	Thermoelectric recirculation, total withdrawals, fresh, in Mgal/d
PC-WSaTo	Thermoelectric recirculation, total withdrawals, saline, in Mgal/d
PC-WTotl	Thermoelectric recirculation, total withdrawals, total (fresh+saline), in Mgal/d
TO-WGWFr	Total groundwater withdrawals, fresh, in Mgal/d
TO-WGWSa	Total groundwater withdrawals, saline, in Mgal/d
TO-WGWTo	Total groundwater withdrawals, total (fresh+saline), in Mgal/d
TO-WSWFr	Total surface-water withdrawals, fresh, in Mgal/d
TO-WSWSa	Total surface-water withdrawals, saline, in Mgal/d
TO-WSWTo	Total surface-water withdrawals, total (fresh+saline), in Mgal/d
TO-WFrTo	Total withdrawals, fresh, in Mgal/d
TO-WSaTo	Total withdrawals, saline, in Mgal/d
TO-WTotl	Total withdrawals, total (fresh+saline), in Mgal/d

LLNL defined terms

PS-CI	Water withdrawn from the public supply delivered to the commercial/industrial sector, in Mgal/d
DO-Consum	Water consumed or evaporated during activities in the domestic sector, in Mgal/d
DO-SaSW	Water used in the domestic sector and discharged to saline surface-water, in Mgal/d
DO-FrSW	Water used in the domestic sector and discharged to fresh surface-water, in Mgal/d
%DO-SaSW(STATE)	Percentage of water used in the domestic sector discharged to saline surface-water in a given state
%DO-SaSW(CA)	Percentage of water used in the domestic water discharged to saline surface-water in California
%Coast(CA)	Percentage of the population living in coastal counties in California
%Coast(STATE)	Percentage of the population living in coastal counties in a given state
CI-Totl	The total amount of water used in commercial/industrial sectors, in Mgal/d
CI-Consum	Water consumed or evaporated during activities in commercial/industrial sectors, in Mgal/d
CI-SaSW	Water used in commercial/industrial sectors and discharged to saline surface-water, in Mgal/d
CI-FrSW	Water used in commercial/industrial sectors and discharged to fresh surface-water, in Mgal/d
MI-Totl	The total amount of water used in the mining sector, in Mgal/d
MI-Consum	Water consumed or evaporated during activities in the mining sector, in Mgal/d
MI-FrSW	Water used in the mining sector and discharged to fresh surface-water, in Mgal/d
LA-Totl	The total amount of water used in the aquaculture sector, in Mgal/d
LA-Consum	Water consumed or evaporated during activities in the aquaculture sector, in Mgal/d
LA-FrSW	Water used in the aquaculture sector and discharged to fresh surface-water, in Mgal/d
LS-Totl	The total amount of water used in the livestock sector, in Mgal/d
LS-Consum	Water consumed or evaporated during activities in the livestock sector, in Mgal/d
LS-FrSW	Water used in the livestock sector and discharged to fresh surface-water, in Mgal/d
IR-Totl	Water consumed or evaporated during activities in the commercial/industrial sectors, in Mgal/d
IR-Consum	Water consumed or evaporated during activities in the commercial/industrial sectors, in Mgal/d
IR-FrSW	Water consumed or evaporated during activities in the commercial/industrial sectors, in Mgal/d
PT-Totl	Water consumed or evaporated during activities in the commercial/industrial sectors, in Mgal/d
PT-Consum	Water consumed or evaporated during activities in the commercial/industrial sectors, in Mgal/d
PT-SaSW	Water consumed or evaporated during activities in the commercial/industrial sectors, in Mgal/d
PT-FrSW	Water consumed or evaporated during activities in the commercial/industrial sectors, in Mgal/d